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(54) Intelligent selection system for electrosurgical instrument

(57) An intelligent selection system for operating an electrosurgical instrument for use by a surgeon that depends primarily on the surgical procedure to be employed. The operating mode as well as other operating parameters can be controlled by the handpiece chosen by the surgeon to perform the procedure. Each handpiece is customized to activate when operated one of several preset operating modes of the electrosurgical

instrument. The electrosurgical handpiece can have a removable section permanently incorporating an electrode adapted for a particular procedure, and configured to connect to a common connector attached at one end to a cable terminating in an end connector for attachment to an electrosurgical instrument. A family of handpieces are preferably configured to removably attach to the common connector and thus could use the same common connector and cable and end connector.

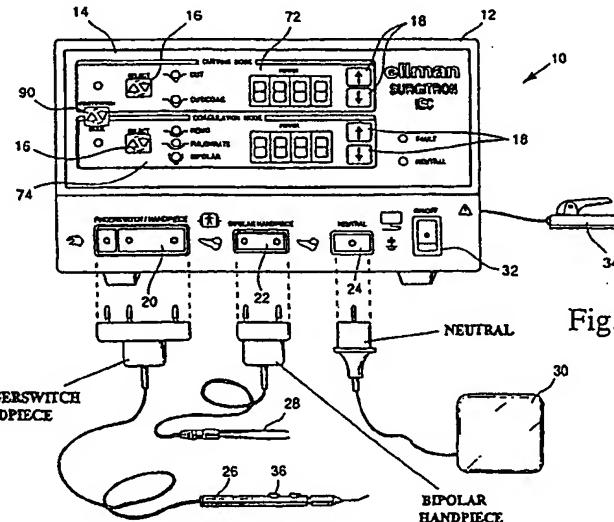


Fig. 1

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Description

[0001] The invention is directed to an electrosurgical instrument, and in particular to an intelligent selection system and a novel RF probe or handpiece for use in such a system for controlling an electrosurgical instrument or apparatus.

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BACKGROUND OF INVENTION

[0002] Electrosurgical instruments are well known and widely used in the medical, dental, and veterinarian fields. They offer the capability of precision cutting and coagulation with electrosurgical currents preferably in the megacycle range using an RF probe or handpiece with, for example, needle, ball, or loop electrodes in a unipolar operating mode or with a forceps in a bipolar operating mode. Ellman International, Inc. makes available an electrosurgical instrument for Radiosurgery which provides on its front panel connectors for receiving the plug of a cable-connected unipolar handpiece and a ground or indifferent plate, as well as connectors for receiving the plug of a cable-connected bipolar electrode. One form of such an instrument is described in USP No. 5,954,686, whose contents are incorporated herein by reference. Such instruments are characterized by different modes and sub-modes of operation. For example, the instrument described in the patent, which is typical of other similar instruments, has a cutting mode, separable into CUT and CUT/COAG sub-modes, and a coagulation mode, separable into HEMO, FULGURATE, and BIPOLAR sub-modes.

[0003] In a typical surgical setting using such an instrument, a surgeon may first use a handpiece while the instrument is in its cutting mode to perform a desired cutting procedure and then desire to use the same handpiece for coagulation of blood vessels while the instrument is in its coagulation mode. To this end, the electrosurgical instrument has on its front panel push buttons or switches for activating internal circuitry for switching the electrosurgical instrument from its cutting to its coagulation mode or vice-versa. A current electrosurgical instrument contains a power-supply-controlled radio-frequency (RF) oscillator which generates RF currents typically in the megacycle range as high-frequency AC waves. For most cutting purposes, the AC waveform is fully filtered to produce an approximate DC waveform. For most coagulation purposes, the AC waveform is partially rectified (commonly half-wave rectification) to produce the characteristic half-wave rectified waveform. This is accomplished by switching in certain rectifier and filter components for the cutting mode, and switching in certain rectifier components for the coagulation mode. This is well known in the art and further description is unnecessary. Suffice to say, the switching action occurs inside the instrument when the front panel controls are activated by the surgeon.

[0004] To simplify mode selection by the surgeon, it is known to place on the handpiece two finger-activated switches that can be connected by appropriate wiring to the electrosurgical instrument and wired in parallel with the front panel switches so that activation of either the finger switches on the handpiece or the front panel switches will allow mode selection. This is similar to the connection and operation of a foot switch that can be used by the surgeon to activate and deactivate the RF currents. More modern electrosurgical instruments, however, do not lend themselves to such a simple approach. The typical modern electrosurgical instrument is computer-controlled, typically by a microcontroller (C); hence simple parallel-connected circuitry may not work satisfactorily. Another problem is that the standard handpiece has only three terminals, one of which is dedicated to carrying the high-frequency electrosurgical currents; hence, mode selection must be carried out in a safe manner using only two of the three terminals.

[0005] A further complication in the use of such instruments is the variety of surgical procedures to which the instrument can be applied. Each surgical procedure typically requires not only a particular electrosurgical mode, such as cut or cut/coag, or hemo, but also may require a different set of mode conditions, such as the power setting and/or a different time duration of power application.

[0006] With four therapeutic waveforms available in current radiosurgery instruments and a wide power range, it is time consuming and memory dependent on the part of the surgeon and/or staff to tune in the correct waveform and power settings for the particular medical procedure to be carried out. Also there may have been occasions when electrosurgical injuries may have occurred due to incorrect waveform settings and incorrect power settings for the chosen procedure.

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SUMMARY OF INVENTION

[0007] A principal object of the invention is an intelligent selection system for an electrosurgical instrument for use by the surgeon that depends primarily on the surgical procedure to be employed.

[0008] Another object of the invention is an intelligent selection system for use by the surgeon that depends primarily on the surgical procedure to be employed and can be controlled by the handpiece chosen by the surgeon to perform the procedure.

[0009] A further object of the invention is a handpiece-controlled electrosurgical instrument in which the choice of the handpiece controls the operating mode of the instrument and, preferably, also the mode conditions, such as the

power setting that is desired for carrying out that particular procedure.

[0010] Another object of the invention is a handpiece for an electrosurgical instrument that eliminates or reduces the chance of the surgeon choosing the incorrect or less than optimum electrode for the surgical procedure to be employed.

5 [0011] A further object of the invention is a handpiece that is dedicated to a particular procedure.

[0012] These objects are achieved in accordance with one aspect of the invention by a novel what may be termed intelligent electrosurgical system that incorporates one or more sets of stored or preset operating modes and conditions that allows the surgeon to select a particular set customized for the particular procedure to be carried out. So if procedure A is to be carried out, then set A is automatically selected, set A prescribing the electrosurgical mode of operation and one or more of the mode conditions specific to the selected procedure. Similarly, if procedure B is to be carried out, then set B is automatically selected, set B prescribing the electrosurgical mode of operation and one or more of the mode conditions specific to the selected procedure, and so on.

[0013] In principle, the selection system can be implemented by operating a multiple-position switch or switches on the front panel of the instrument, each switch or switch position being associated with one of the stored sets of operating modes and conditions. However, in accordance with a preferred feature of the invention, the selection is incorporated at least in part into the handpiece chosen by the surgeon. While it is possible to build into the handpiece a fingerswitch for each of the stored sets of modes, this has the disadvantage that if the surgeon presses the wrong fingerswitch, then the wrong operating mode for the current procedure may be inadvertently selected. It is therefore preferred in accordance with another feature of the invention to provide a family of intelligent or smart handpieces, each dedicated to a particular procedure.

[0014] In this preferred embodiment of the invention, each dedicated handpiece has incorporated in it means for generating a unique control signal that when processed by a computer in the electrosurgical instrument will automatically select that particular set of mode conditions specific to the procedure to which the handpiece is dedicated. There a number of different ways in which this feature can be implemented and the description that follows will describe several of the ways.

15 [0015] It is also possible to go to the next step and control the appearance of the handpiece, for example, by color-coding, so that the surgeon understands that a specific colored handpiece is associated with a specific procedure, which will further minimize the possibility of surgeon error.

[0016] As a further feature of the invention, instead of providing handpieces which can typically receive one of several interchangeable electrodes, the electrode appropriate for the specific procedure can be molded into the intelligent handpiece and made a permanent integral part of the handpiece, further minimizing the possibility of the surgeon choosing the wrong electrode for the specific procedure.

[0017] In still a further preferred embodiment, the handpiece construction is similar to the standard two-fingerswitch, three-terminal handpiece used heretofore except that means are included in the handpiece such that, when a first fingerswitch is activated, a first current level signal is outputted and when a second fingerswitch is activated, a second current level signal is outputted, both preferably from the same terminals. The means are chosen such that a C in the instrument can distinguish the two current levels and activate the appropriate operating mode, for example, a cut mode for that particular procedure or a hem mode for that particular procedure. In a preferred embodiment, the surgeon has available a family of such handpieces each configured and adapted for either the same procedure, as for example procedure A is to be carried out, or for a different procedure in the surgeon's specialty. So, for example, if best for that procedure. Similarly, if procedure B is to be carried out, then handpiece B is selected which includes the electrode that the surgeon deems best for procedure B. Fewer electrode errors are possible, in another preferred embodiment, because the handpiece may be labeled for that procedure or otherwise visually distinguishable from other handpieces, as, for example, by shape or color-coding, and the optimum electrode for that procedure is already pre-attached to the handpiece. While this arrangement seems to imply greater cost, as multiple handpieces are required to cover all the procedures that the surgeon typically performs, the cost to manufacture each handpiece is far below that of the standard handpiece and so the overall cost may not be significantly greater, keeping in mind the comfort of knowing that errors are less likely to occur.

[0018] In yet a further preferred embodiment of the invention, to further reduce costs, the handpiece comprises a common connector attached at one end to a cable terminating in an instrument end connector for attachment to the instrument, and at its other end it is adapted to receive and hold and electrically connect to the handpiece proper itself, meaning a handle for the surgeon to hold and the attached electrode. Each member of the family of handpieces are preferably configured to removably attach to the same common connector and thus could use the same common connector and cable and end connector for connecting to the instrument as the source of RF electrosurgical currents.

20 As a result, the user need purchase only one common connector/cable accessory usable with any of the handpiece family members.

[0019] The handpieces of this feature of the invention are uniquely suited to incorporate the intelligent selection system feature of the invention as each handpiece here already has an electrode pre-attached so it is only necessary

to incorporate in that handpiece the appropriate electrical component to implement the intelligent selection system feature when it is combined with an electrosurgical instrument containing the means to interpret and implement the dedicated handpiece concept.

5 [0020] For convenience of explanation, A handpiece section@ as used herein shall mean the removable handles each holding an electrode, A cable-connector section@ shall mean the common connector for the handles, attached cable, and end connector for the instrument; and A handpiece@ or A probe@ shall mean the integration or combination of the two sections making up a working unit.

10 [0021] The various features of novelty which characterize the invention are pointed out with particularity in the claims annexed to and forming a part of this disclosure. For a better understanding of the invention, its operating advantages and specific objects attained by its use, reference should be had to the accompanying drawings and descriptive matter in which there are illustrated and described the preferred embodiments of the invention, like reference numerals or letters signifying the same or similar components.

SUMMARY OF THE DRAWINGS

15 [0022] In the drawings:

Fig. 1 is a schematic view of one form of electrosurgical instrument in accordance with the invention;
 Fig. 2 is a circuit block diagram of one form of system circuitry for the electrosurgical instrument of Fig. 1;
 20 Fig. 3 is a flow chart illustrating how the system circuitry of Fig. 2 can be software controlled and operated in accordance with the invention;
 Fig. 4 is a schematic view showing a handpiece connected to an electrosurgical instrument in accordance with the invention;
 Fig. 5 is a circuit schematic of one form of electrical circuit for the handpiece of Fig. 4;
 25 Fig. 6 illustrates schematically the interface connections in one embodiment between the handpiece of Fig. 4 and the electrosurgical instrument;
 Fig. 7 illustrates schematically the circuit connections in another embodiment between the handpiece of Fig. 4 and the electrosurgical instrument;
 Fig. 8 is a partial perspective view of one form of 3-button handpiece according to the invention;
 30 Fig. 9 is a circuit schematic of one form of 4-button handpiece according to the invention;
 Fig. 10 is a block diagram showing how the handpiece of Fig. 9 can be interfaced to a microcontroller in the electrosurgical instrument;
 Fig. 11 is a flow chart indicating how the electrosurgical instrument can be programmed to operate with smart handpieces according to the invention;
 35 Fig. 12 shows a schematic block diagram of another embodiment of an electrosurgical instrument according to the invention;
 Fig. 13 is a flow chart illustrating one form of program for activating the MANUAL or AUTO mode of an electrosurgical instrument according to the invention;
 Fig. 14 is a top view of one side of one form of electrosurgical dedicated handpiece in accordance with the invention;
 40 Fig. 15 is a top view of another side of just the handpiece section of the handpiece of Fig. 14;
 Fig. 16 is a view along the lines 16-16 showing the outer triangular shape of the handpiece section of Fig. 15;
 Fig. 17 is a top view of the common connector of the cable connector section shown without the cable of the handpiece of Fig. 14;
 45 Fig. 18 is a longitudinal cross-sectional view of just the electrically-insulating part of the cable connector section of Fig. 17;
 Fig. 19 is a longitudinal cross-sectional view along the line 19-19 of the cable connector section of Fig. 17;
 Fig. 20 is a cross-sectional view of the widened part of the handpiece section of Fig. 14, also representing the section along the line 20-20 of Fig. 23;
 Fig. 21 is a cross-sectional view of the tapered part of the handpiece section of Fig. 14, also representing the section along the line 21-21 of Fig. 24;
 50 Fig. 22 is a longitudinal cross-sectional view along the line 22-22 of the handpiece section shown in Fig. 24;
 Fig. 23 is an elevational view of one side of another form of handpiece section in accordance with the invention;
 Fig. 24 is an elevational view of another side of the handpiece section of Fig. 23;
 Fig. 25 is an elevational side view of one form of the internal electrically-conducting tube of the handpiece section in accordance with the invention shown with an attached electrode;
 55 Fig. 26 is an elevational top view of the electrically-conducting tube of Fig. 25;
 Figs. 27, 28, 29, and 30 are elevational views of different typical forms of electrodes that can be attached to the handpiece of the invention.

DETAILED DESCRIPTION OF PREFERRED EMBODIMENTS

[0023] One form of an electrosurgical instrument 10 according to the invention is illustrated in Fig.1. It comprises a system unit 12 having a box-like housing comprising at the front a control panel 14 for the instrument. The control panel includes touch switches 90 for selecting cutting or coagulation modes and touch switches 18 for controlling the power output by increasing or decreasing in steps the power, as indicated by upper and lower digital displays showing all 8's. At the bottom are output female connectors 20, 22, 24 for plugging in, respectively, at the left, a fingerswitch-controlled unipolar handpiece 26; at the center, a bipolar handpiece or forceps 28; and at the right a single or split neutral plate 30. An on-off power switch 32 is at the far right. The circuitry used to provide a fingerswitch-controlled unipolar handpiece may be of the type described in connection with the control unit 50 of US Patent No. 4,463,759, whose contents are herein incorporated by reference, which circuitry is in this case incorporated in the console unit 12. A connector (not shown) is provided at the side for receiving a conventional footswitch 34. Both the unipolar and bipolar handpieces can be simultaneously connected to the system unit 12 and operated in any order without touching the system unit or the control panel when the control panel has been preset or activated at the desired powers by each of the handpieces. For example, if the surgeon determines that s/he is going to perform a cutting procedure with a particular electrode, then s/he can set the cutting mode power on the upper digital display to, say, 80 watts by the up/down buttons 18. (Typically, these units are designed to supply up to 100 watts of RF power to either handpiece.) For coagulation with the bipolar handpiece, s/he may desire to use, say, 50 watts, which can also be set on the lower digital display by the up/down buttons 18. In this first embodiment, the internal circuitry is controlled in a known manner so that, when the fingerswitch unipolar handpiece is used, then RF power can be supplied to the electrode in the unipolar handpiece when a fingerswitch 36 on the handpiece 26 is depressed. However, when it is desired to use the bipolar handpiece 28, then the footswitch 34 is depressed, which then supplies RF power to the forceps of the bipolar handpiece. This result is a consequence of software control such that, while the machine mode is selected such that the fingerswitches on the unipolar handpiece can be used to apply power to the electrode (footswitch mode non-selected), only the footswitch can be used to apply power to the bipolar handpiece. This prevents power selected for the unipolar handpiece to be applied to the bipolar handpiece, and vice-versa. On the other hand, when it is not intended to use the bipolar handpiece and the footswitch mode is selected, then the footswitch can be used to operate the unipolar handpiece.

[0024] One form of the RF circuitry to achieve the foregoing operation is illustrated in the block diagram of Fig. 2. The block 40 in the upper left contains two independent conventional RF oscillators generating, preferably, RF oscillations at 8.0 and 3.42 MHz respectively. As will be explained in greater detail below, the arrow 42 labeled CPU represents a selection signal generated by a conventional microcontroller under software control and inputted into the block 40 to select for operation either the 8.0 MHz oscillator or the 3.42 MHz oscillator. Both oscillators are constantly on when the power switch is activated, and the CPU selection 42 determines which of third (8.0 MHz) or fourth (3.42 MHz) frequencies are outputted to the divide-by-2 block 44, resulting in an RF carrier 46 at either the first (4.0 MHz) or the second (1.71 MHz) frequency. That carrier is then pre-amplified in block 48 and inputted to a conventional modulator stage 50. Also input to the modulator stage is a modulating signal 52 derived from a CPU selection signal 54 and a D/A converter 56. The modulations referred to are the different output waveforms used for the known CUT, CUT/COAG, HEMO, and FULGURATE modes. These typically are: CUT -CW (full-wave rectified and filtered) output with maximum average power; CUT/COAG -full-wave rectified but unfiltered, deeply modulated, at 37.5 or 75 Hz rate, envelope with approximately 70% average to peak power ratio; HEMO- half-wave rectified and unfiltered, deeply modulated, at 37.5 or 75 Hz rate, envelope with approximately 35% average to peak power ratio; FULGURATE (or Spark-Gap Wave)-deeply modulated, 3.6 KPPS random rate with approximately 20% average to peak power ratio. Selection of the bipolar mode will automatically select the HEMO mode. The invention is not limited to these quantities.

[0025] The RF power generating circuitry may be of the well known tube-type described in US Patent No. 3,730,188, whose contents are herein incorporated by reference, which is capable of generating a fully-rectified, filtered RF current for cutting, a full-wave rectified current for combining cutting and coagulation, and a half-wave rectified current for coagulation. Alternatively, the RF power generating circuitry can be of the well-known solid-state type capable of generating the same kinds of waveforms. The RF circuitry, as such, is not part of the present invention, as such circuits are well-known in the prior art. In this case, the RF circuitry provides two different frequencies of operation, a first high frequency in the range of 3.8-4.0 MHz, and a second high frequency in the range of 1.7-2.0 MHz, which is easily obtained by providing a known RF generator that provides outputs at these first and second higher frequencies and providing a simple known divide-by-two circuit for obtaining dual outputs at one half of the first or second frequency. Both outputs can be separately amplified and processed and made available at the console's output connectors depending on the switches activated. The present invention is not limited to the dual-frequency output operation.

[0026] After the modulated carrier has been generated at 58, it is processed through a standard driver 60, a transformer 62, and a power amplifier 64 controlled by a bias signal and whose input is monitored for safety's sake by a power tester circuit 66 under control of the CPU. The power amplifier output 68 is inputted to a mode selection block

70 under control of a signal from the CPU. The mode selection is made by the user by activating the upper panel 72 by pressing switch 16 in the upper panel, or the lower panel 74 by pressing switch 16 in the lower panel. That selection, made in conjunction with the selection 42, directs the output RF energy along the upper branch 76 or the lower branch 78. Both branches contain an isolation transformer 80 and a sensor 82 for operating indicators and preventing both branches from being activated at the same time. In other words, when the monopolar sensor 82 senses RF energy, the bipolar branch is disabled, and when the bipolar sensor 82 senses RF energy, the monopolar branch is disabled. The outputs 84, 86 shown at the right are directed to the connectors 20 and 22, respectively.

5 [0027] In this embodiment, the instrument is software controlled with the user supplying the switch inputs. One form of software control is illustrated by the flow chart depicted in Fig. 3. When the on-off switch 32 is toggled on, the 10 microcontroller (not shown) is placed in its standby condition represented by block 88. The first action by the user is to select cutting mode or coagulation mode by pressing the switch 90 on the front panel, then pressing the upper or lower select switch 16 which determines which of the cutting or coagulation modes will be operable. If the coagulation mode is selected, the lower select switch 16 is used to select unipolar (HEMO or FULGURATE) or bipolar mode. The 15 fingerswitch handpiece 26 operates exclusively of and independent from the footswitch mode selection 90 for all unipolar modes. This ensures that RF currents are available exclusively and at all times at one of the sockets 20, 22. If no such user action has occurred, tested at block 92, the CPU returns 94 to its standby condition. If a selection has been made 96, control is passed to the test block 98, which tests whether lower switch 16 has selected the bipolar mode. If yes 100, the circuitry to generate the 1.7 MHz carrier is selected at block 102, and control passes to the test block 104 which tests whether the footswitch 34 has been pressed, which is the only way by which 1.7 MHz currents 20 can be made available at the bipolar handpiece socket 22. If no, the CPU returns 106 to its standby mode; if yes 107, RF energy is supplied to the bipolar handpiece socket 22.

25 [0028] If the bipolar mode was not selected at test block 98, then the circuitry to generate the 4.0 MHz carrier is selected at block 108, and control passes to a series of test blocks 110, 112, 114 which test, respectively, whether the CUT, HEMO, or FULGURATE modes have been selected by the user by means of upper and lower switches 16, which then provide the RF energy at 4.0 MHz at the monopolar connector output 20. If also the footswitch 34 was pressed, then the footswitch 34 can control when the RF energy is supplied to the handpiece 26; otherwise, the fingerswitch 26 on the unipolar handpiece 26 controls the delivery of RF energy to the patient.

30 [0029] In this operation using the instrument front panel switches, the ground plate 30 is always attached to the patient, and the surgeon can perform any desired unipolar or bipolar electrosurgical procedure. When both the unipolar and bipolar handpieces are plugged into the instrument console 12, then the desired operating conditions for each can be preset as desired. Then whichever handpiece is picked up and operated by the surgeon will automatically determine which is supplied with the appropriate RF currents. Thus, if the bipolar handpiece is selected and the footswitch activated, the bipolar handpiece will be supplied with 1.7 MHz currents at the power setting manually selected by the user. On the other hand, if the unipolar handpiece is selected and its fingerswitch 36 activated, the unipolar handpiece will 35 be supplied with 4.0 MHz currents at the power setting manually selected by the user. This operates on a first-come, first-served basis, which thus allows the surgeon to use the CUT mode for cutting with the unipolar handpiece followed with the bipolar handpiece for closing off any bleeders exposed during the cutting.

40 [0030] What has so far been described is the manual way of operating the instrument with conventional handpieces. In accordance with a feature of the present invention, instead of or in addition to using the manual mode of operation, an automatic mode is incorporated that is determined by the procedure to be performed by the surgeon or by the handpiece selected by the surgeon for the procedure. Preferably, the desired mode is selected by plugging an intelligent handpiece into the instrument. One example of such a handpiece will now be described in connection with Figs. 4-7.

45 [0031] In this example, the handpiece comprises a generally conventional handpiece 110, with certain changes added in accordance with the invention, explained below, connected to a 3-line connector or terminal 112 which in turn is connected by way of a multi-line cable 114 to a control system 116 in turn connected to or a part of, as is more common, a conventional electrosurgical instrument 118 of the type illustrated in Fig. 1. The electrosurgical instrument 118 comprises an RF generator with the usual circuits to generate current waveforms in the high-frequency megacycle range, for example, 1-4 MHz, and also includes various circuit components to control the shape of the waveforms for various operating modes, including the cutting and coagulation modes as above described. The selection can be made by 50 means of push buttons or switches on the control panel of the instrument. In the more modern electrosurgical instruments, the control is usually exercised by way of a computer, usually a C, with the controls determining which inputs of the C are activated, which controls which outputs of the C are enabled, in turn in one embodiment switching in or out of the power-supply-controlled RF circuit rectifying and filter components (not shown as well known in the art) for the different modes selected.

55 [0032] In this preferred embodiment, the handpiece 110 comprises a pencil-type housing 111 on which are provided two fingerswitches 120, 122 for mode selection. In addition, it contains a chuck or other holding device 124 for receiving the shank of a conventional removable electrosurgical electrode 126. The shank is typically of metal, as is the chuck, which is connected by an electrical conductor 130 to one of the terminals of the connector 112. The two fingerswitches

120, 122 are also connected to the other two of the three terminals on the connector 112.

[0033] Fig. 5 shows the internal circuitry of the handpiece 110. The chuck 124 and line 130 carry the RF currents within the handpiece housing 111 to the electrode when inserted in the chuck 124. This uses the bottom terminal of the connector 112. The upper two terminals are connected inside of the housing 111 as shown to the two fingerswitches 120, 122. A resistor 132 is also mounted inside the housing 111. As will be observed, when switch 120 is closed, the circuit bypasses the resistor 132; however when instead switch 122 is closed, the circuit through the upper two terminal includes the resistor 132 in series.

[0034] As schematically indicated in one embodiment illustrated in Fig. 6 for identifying the inputted control signal, the top terminal is grounded for safety's sake and together with the bottom terminal connected to an isolation transformer 136 which in turn is coupled to the RF oscillator. The center terminal is connected via a current limiting resistor 138 to a DC voltage source 140 which provides a DC current to a DC amplifier 142 whose magnitude is determined by which of the two fingerswitches are activated. When fingerswitch 120 is pressed, which bypasses the resistor 132, a higher level of DC current is fed to the amplifier 142. When fingerswitch 122 is pressed, which includes the resistor 132 in the circuit, a lower level of DC current is fed to the amplifier 142. The C is adjusted to distinguish between the two DC current levels and in a known way to activate one or more of its outputs which will select the desired operating mode that has been associated with the corresponding fingerswitch. Alternatively, the output from the amplifier 142 can be inputted to a DC comparator to which a reference current is supplied, with the comparator determining, as is well known, whether the input current is below or above the reference, with the comparator outputting, say, a "1" when the output current exceeds the reference, or a "0" when the output current is below the reference. The C can then be set to respond to the digital "1" or "0" to select the operating mode.

[0035] In the preferred embodiment, the left fingerswitch 120 is used to select the cutting mode, and the right fingerswitch 122 is used to select the coagulation mode.

[0036] As will be observed, by the simple expedient of adding one or more small resistors 132 to the standard handpiece to change the DC current level established depending upon which of the two fingerswitches are activated, while continuing to use the standard three-terminal connector, it is possible to provide a simple DC output from two terminals which is easily interfaced to a standard C to control the operating mode of the electrosurgical instrument. The use of a DC circuit eliminates the possibility of noise or other interfering signal from the RF currents at the third terminal that can cause accidental mode switching.

[0037] Fig. 7 illustrates another preferred embodiment in which the cut and coag waveforms are generated in a somewhat different manner. In this embodiment, a conventional RF oscillator 150 generates a continuous wave (CW) output that is fed to a conventional mixer 152. The latter is controlled by a microcontroller 156. The microcontroller 156 in turn receives a low-level control signal or a high-level control signal from the handpiece 110 depending upon whether fingerswitch 120 or 122 is pressed. The microcontroller 156 may be software controlled, and in response to the handpiece signal input causes the modulator to produce no output or a signal at a 100-120 Hz rate which is ON for approximately one-half the cycle and OFF for the other half. The mixer 152 thus outputs, when no modulator signal is inputted, the unmodulated CW output for the cut mode; and when the described 100-120 Hz signal is inputted, the mixer outputs a deeply-modulated RF carrier envelope with an average to peak ratio of about 50% for the coag mode.

[0038] In this second embodiment, the output waveform is no longer dependent upon the power supply. An AC control current can be used in place of the DC current, at a voltage of about 5 volts at a frequency of about 300-500 KHz, which is below the megacycle range of the RF output to minimize interference.

[0039] In a further preferred embodiment of the invention, the current level controlling means is a simple impedance, preferably a resistor, mounted in the handpiece and connected to the two fingerswitches such that it is in or out of the circuit depending upon which fingerswitch is activated.

[0040] Besides low power and low cost, the fingerswitch mode controller of the invention is easily operable with relatively low frequency AC or direct currents (DC). This is important because the control circuitry that carries the two AC or DC levels of current is housed in the same pencil-type handpiece that includes the line carrying the RF AC currents which is a possible source of RF interference with such control systems for mode selection. For safety's sake it is important that no accidental undesired switching between the two modes occurs while a surgical procedure is being carried out. In addition, the system of the invention offers the advantages of accessibility and versatility, providing the surgeon all the benefits of fingerswitch selection of either electrosurgical mode.

[0041] The preferred embodiment uses a 100 ohm resistance for the mode selection resistor 132. With an AC current established at the upper two terminals of about 70 mA when the fingerswitch 120 is closed, when instead the fingerswitch 122 is closed, the introduction of the series resistor 132 reduces the DC current to about 3 mA. This difference is sufficient to be detected and when amplified or digitized can be used to control the C. However, it will be apparent to those skilled in the art that the choice of resistance depends upon a number of factors including the type of C used and the circuit components between the C and the handpiece, and other resistance values would be appropriate with other circuits and is deemed within the scope of the invention. The benefit of the 100 ohm resistor is that, as a small wattage component, it is very small and easily fitted within the pencil-like structure of the housing 111, which typically

has a diameter of about 1/2 inches or less, for example 3/8 inches, and a length of about 2 3/4 inches. Also, the invention is not limited to resistors as other small size impedances could be substituted capable of sufficiently changing the DC or AC current level upon activation of one or the other fingerswitch.

5 [0042] In the preferred mode of operation, the RF power is in a frequency range exceeding 1 MHz, 1.7-4 MHz being preferred. However, the invention is not so limited and other frequency ranges for electrosurgical procedures are also considered within the scope of the invention.

10 [0043] What has so far been described is how a novel construction of the handpiece can be used to generate a control signal to operate a C which then controls the electrosurgical instrument to provide the correct mode of RF operating currents to the handpiece. It will be understood that the symbol for a microcomputer C is also used herein to signify a microcontroller, commercial embodiments of which both contain for all practical purposes the same computing elements including a ROM to store a program in the usual way. In these embodiments, a first button of the handpiece is used to select unipolar operation and a second button is used to select bipolar operation. The invention is not limited to two-button handpieces but also includes handpieces with one or more additional buttons. Fig. 8 illustrates the internal construction of a handpiece provided with 3 buttons and 2 internal impedances and the standard 15 3-terminal output, and Fig. 9 is the schematic of a 4-button handpiece with 3 internal impedances, an internal non-volatile memory, e.g., an EEPROM, and a 5-terminal output. The Fig. 8 view is with the housing omitted to show one possible internal construction which comprises in front the electrode holder 158, three finger switches 162, 164, 166, two resistors 168, 169, and a cable holder 170 at the rear which terminates in a 3-terminal connector (not shown). PC boards 172, 173 can also be mounted below as shown if needed.

20 [0044] Fig. 9 illustrates one possible schematic for a 4-button handpiece SW1-SW4 with 3 impedances R1-R3 in the form of resistors. In this embodiment, a 5-terminal connector 174 is provided to increase the number of control signals that can be accommodated, as well as provide connections to an internal EEPROM 176 for reasons to be explained below. It is understood that the invention is not limited to separate connections for the finger switches and the EEPROM. As is well known in the C used in watches, the same button or key can be used for different functions by having the C 25 sense multiple button presses, and associate for example function A with one key press and function B with two quick presses of the same key, and the same approach can be used in the invention but the illustrated arrangement is preferred.

30 [0045] A block diagram illustrating the interfacing arrangement of a C to the handpiece is shown in Fig. 10. In this embodiment, the C 178 is connected via conventional optical isolation 179 to the handpiece 180. The microcontroller 178 can communicate through a serial protocol to the EEPROM 182 (electrically erasable read only memory) incorporated inside the handpiece 180. Optical isolation is desirable to protect the processor 178 from RF noise generated while the instrument's output is active. The memory 182 in the handpiece can be read from and written to by the processor 178 to allow the handpiece to store a variety of configuration and operational information.

35 [0046] A further example of how the selected mode, power, and time can be actually implemented in the instrument is illustrated by the flow chart in Fig. 11. Recall that the handpiece need not be limited to remembering or setting modes and power levels but must cooperate with the local electrosurgical instrument to provide the functions as described above. It will work with the Surgitron IEC II (Dual Frequency) electrosurgical instrument manufactured by the Ellman company but is obviously not limited to use with that particular system so long as the current system has been appropriately modified to include the necessary programmed C to provide the functions as described. Some of those functions 40 are illustrated in the flow chart of Fig. 11. The starting point is the initialization block 184. If no handpiece, sometimes referred to for brevity herein as "probe", has been connected to the instrument or it is unconfigured 186, the program branches to block 187 to check whether a probe has been connected. If the answer is no, the program loops back to block 187. If the answer is yes, the program falls through to block 188 to check whether the system is configured. If the answer is no, then, under control of the program, the system controller 178 accesses the internal EEPROM 182, 45 reads 189 the EEPROM settings, and at block 190 then configures the instrument (system) to the correct mode and condition settings. The program then returns to block 187, proceeds then to block 188 and branches to the right to the block 192 which allows operation including if desired display of the operating parameters to the user based on the EEPROM settings.

50 [0047] In the read probe block 189, the C receives an unambiguous indication of what buttons are physically on the probe and what modes they initiate. A probe could be configured to allow a unit to work only in one or certain modes, and could also be configured to allow the electrosurgical unit to put out only certain ranges of power in each allowed mode. In addition, the probe memory 182 could be used to implement the number of uses or elapsed time of use functions. A new probe might be set to 50 uses or 100 minutes of use to retain its reliability. When a probe has run out of time/uses it could be recharged (reprogrammed) or thrown away. The probe is typically factory-configured to define 55 the above information. The instrument reads the probe data and configures itself. The hardware used to interface the handpiece to the instrument can be the same as that described in connection with Figs. 1-7 above.

[0048] The mode and condition-setting functions can be incorporated in the probe or handpiece as just described or in the electrosurgical instrument or in both. In the case of the electrosurgical instrument, there are a number of

different ways in which a handpiece key press or 2 key presses can select the mode and conditions of a particular procedure. The simplest way is to incorporate in the instrument a conventional look-up table that contains the mode and operating conditions for a number of different procedures, with the look-up table responding to a particular control signal (key) from the handpiece to vector to a subroutine which, equivalent to the surgeon's activation of the front panel switches, automatically switches the electrosurgical instrument to the correct mode and sub-mode and automatically sets the power to a specific value or to allow a specific range of values that will not harm the patient. A timer can also be included in the electrosurgical instrument so that the ON time of the instrument does not exceed a maximum time for the application of electrosurgical currents to the patient undergoing that procedure. As one example, a handpiece can be provided that is tailored for surgical procedures carried out with the instrument set at the cutting mode and the Cut or Cut/Coag sub-mode. The handpiece has incorporated in it a known blade electrode. For many cutting procedures, a typical power setting for tissue incisions is, say, 10 Watt, and a typical cutting duration rarely exceeds 10 sec. The handpiece tailored for cutting has a resistor of say 40 ohms connected to finger switch-2, and a resistor of say 30 ohms connected to finger switch-3. So, when finger switch-2 is pressed, a control signal of, say, 20 mA is sent to the instrument housing the C and when finger switch-3 is pressed, a control signal of 30 mA is sent to the instrument housing the C.

[0049] Referring now to Fig. 12, which shows a schematic block diagram of an electrosurgical instrument according to the invention, inside the housing is a conventional analog-to-digital (A/D) converter 300 which converts the received control signals to a digital number representing a key to the look-up table. The digital number generated by the A/D converter when receiving a 20 mA signal and that generated when receiving a 30 mA signal are different and each corresponds to a different entry or key into the look-up table and thus a different subroutine is executed depending upon whether the control signal comes from the second or the third finger switch. The key outputted from the A/D converter is inputted to the look-up table 302 which, as illustrated below, could store three data items that are outputted to the RF generator 304 of the instrument. The first 306 is the mode-select signal which switches the RF generator to, say, the Cut mode. The second 308 is the sub-mode-select signal which switches the RF generator to, say, the Cut sub-mode. The third 310 is the power select signal which switches the RF generator to the desired power setting. In this particular case, assuming that finger switch-2 is associated with a Cut sub-mode at 10 Watt, then the outputs from the look-up table switch the instrument into the Cut sub-mode, and sets the power setting at 10 Watt, and, of course, in the usual way the activation of the finger switch causes the C to execute the program illustrated in Fig. 3 resulting in the application of 4 MHz electrosurgical currents to the active electrode mounted at the end of the handpiece. A similar action takes place when finger switch-3 is pressed except that the different control signal when converted to a different digital number corresponds to a different entry or key into the look-up table resulting in switching of the instrument to the Cut/Coag sub-mode with a power setting of say 15 Watt. If desired, the look-up table can also incorporate a data item representing a duration not to exceed a fixed amount.

[0050] The mode selection and power settings is a straight forward implementation using the principles and circuitry described in connection with Figs. 1-3. The look-up table is an example of a database as a set of records each including an identifying key to uniquely identify the record. In the relatively small database involved here, it can be implemented as an unordered list in which any record is easily accessed by inputting an identifying key which then outputs the record. The key here is the control signal generated by a particular key press, converted to a digital number, and the record outputted could be, for example, a digital word the individual bits of which or combinations of bits represent a mode, sub-mode or mode condition (explained below). Alternatively, the database can be implemented as a table of records indexed by identifying keys, either as a 1-dimensional table or as a list of records. In either case, the inputted key produces a unique output record. The specific way of accomplishing outputting of records upon inputting of keys is not part of the present invention and is well known in the art.

[0051] Assuming the outputted record is a 16 bit word stored in a free register in the C, then the C can easily be programmed to access the bits to select specific modes and conditions. For example, the first bit can represent by a 0 the cutting mode and by a 1 the coagulation mode; the 2nd and 3rd bits can represent cut by 00 and cut/coag by 01 in the cutting mode, and in the coagulation mode 0 as hemo, 01 as fulgurate, and 10 as bipolar. The power setting can be represented by the 4th, 5th, 6th, 7th, and 8th bits. Five bits can represent 32 different power settings. Assuming a power range of 1-64 watt, then 32 settings in that range separated by 2 watt intervals can be defined by the five bits. If finer divisions are required, 6 bits will define 64 different possible settings. Without a timer, then, even an 8 bit word will suffice. If timer settings are required, with finer power divisions, 7 bits of a 16 bit word will remain to define the duration settings which typically range from 1-50 sec. Similarly, by going to a 32 bit word, common in today's technology, then 16 bits will be available to select other conditions. Possibilities include: 1) in several procedures, it is common to irrigate the tissue cut or ablated. These additional bits can be used to turn on and off an irrigation pump supplying fluid to a tube mounted on the handpiece; and 2) it is also common to apply suction to the surgical site to remove undesirable plumes and odors. These additional bits can be used to turn on and off a vacuum pump supplying suction to a tube mounted on the handpiece.

[0052] In the latter embodiment, the database was incorporated inside the electrosurgical instrument, and the access

keys supplied by the control signals inputted from the handpiece when specific keys are pressed. As a further alternative using two look-up tables, a non-volatile memory is provided in the handpiece (see Fig. 10) and stores in a lookup table in the memory 1-3 digital words which represents the desired electrosurgical modes and conditions. The C in this case is located in the instrument. Assuming a 3-finger-button switch handpiece, 3 different control signals can be generated by the handpiece in response to pressing any one of the 3 buttons. When converted to a digital number, the handpiece control signal can act as an identifying key for a simple look-up table in the instrument, in which case the single output from the instrument look-up table is an identifying key for the handpiece lookup table. When the latter from the instrument look-up table is returned via a multiplexed data line to the handpiece look-up table, the handpiece look-up table will return on the same data line in a different time slot one of the 3 digital words stored in the handpiece look-up table.

5 That returned word can be processed by the C in the same manner as described above. In both of these embodiments, the handpiece becomes a dedicated or customized handpiece which generates a unique control signal from one or more of its buttons which represents instrument modes and conditions for one or more specific procedures, or generates a unique digital word when one or more of its buttons are pressed which also represents instrument modes and conditions for one or more specific procedures. In other words, the handpiece is factory-constructed or programmed to 10 perform only certain procedures, and each surgical specialty will therefore require a family of several of these dedicated handpieces in order to perform several different procedures. This assures the surgeon that if he selects the right handpiece, then it is less likely that he will cause inadvertent injury to the patient. This can also be enhanced by color-coding the handpieces differently, so, for example, the blue colored or marked handpiece is specific to a cutting operation, and the red colored or marked handpiece is specific to a coagulation procedure.

15 [0053] In the 4-button handpiece schematically illustrated in Fig. 9, the 4 buttons, SW1, SW2, SW3, SW4, are connected to a 5-pin connector 174 which can be plugged into a system with a matching connector, or to the system illustrated in Fig. 1 with an intervening adaptor and circuitry to allow three of the connector connections to be multiplexed to share the smaller number of connectors on the system panel. SW1 with no series resistor will produce a first control signal when pressed; SW2 with series resistor R1 will produce a second control signal when pressed; SW3 with series 20 resistor R2 will produce a third control signal when pressed; and SW4 with series resistor R3 will produce a fourth control signal when pressed. These signals are outputted to terminal connections 2 and 3. The EEPROM 176 can be accessed via terminal connections 4 and 5 and conventional multiplexing. Terminal 1 is reserved for receiving and applying the selected RF electrosurgical currents from the system unit.

25 [0054] The table appearing below shows examples of how the control handpiece impedances can be arranged. In this case, each impedance is dedicated to a particular mode and a specific power level. For example, the impedance ZC00 is designated for the CUT mode with a power level of 100 Watts. By impedance in this context it will be understood 30 is meant an incorporated element in the handpiece that causes the latter to output a particular control signal for this particular mode and output power setting. Thus, the incorporated impedance represents a corresponding pre-set function or electrosurgical procedure. A doctor may select the handpiece with the corresponding pre-set function that will 35 serve the purpose of the desired procedure. The listed impedances and their designated modes and power levels are merely examples of how each impedance can be matched to its pre-set function.

TABLE

Impedance No.	Waveform Mode	Waveform Sub-Mode	Power	Misc.(for other items if needed)
ZCOO	CUTTING	CUT	50	
ZBCO	CUTTING	CUT/COAG	40	
XNFO	COAGULATION	HEMO	20	
XSHO	COAGULATION	BIPOLAR	10	

40 [0055] In this example, the letter Z can represent the CUTTING waveform mode; the letter X can represent the COAGULATION waveform mode; the second letter the relevant sub-mode; the third and fourth letters various conditions such as power or duration. Sometimes the duration value in the record can represent a maximum value. This simply means that that value is inserted to a countdown timer 312 (Fig. 12) which starts counting down when the RF electrosurgical currents are supplied to the handpiece electrode and will automatically shut down the electrosurgical currents when the timer reaches zero, as a safety feature. Of course, the physician can as usual stop the flow of currents by simply releasing the handpiece button whenever s/he desires.

50 [0056] In principle, the number of impedances has no limit. It can be as much as required to meet the desired pre-set functions. That is to say, the number of handpieces provided equals the number of desired pre-set functions. Many kinds of surgical procedures require many kinds of different functions. Many kinds of different functions require many kinds of handpieces. The number of impedance that can be used will be chosen to match as many of the handpiece 55

functions as desired. Each handpiece has one or more buttons to activate the electrosurgical generator. The 3-button handpiece is one example of how a handpiece may control more than just one pre-set function. The smart electrode handpiece may have as many button switches as required to control the variety of pre-set functions by installing the corresponding impedances into the smart handpiece.

5 [0057] The output from the smart or intelligent handpiece derived from the impedance is an analog voltage whose value is determined by the value of the impedance, which may be, for example, a resistor. The resistor analog voltage may be converted in a conventional A/D convertor to a digital number for the purposes taught above. However, the resistor is not a unique selection. The sensor can be any passive and/or active element that includes resistor, inductor, capacitor, transistor, and even an integrated circuit.

10 [0058] The C processes the received analog sensing signal/voltage through the A/D converter, and then matches the signal to a pre-set function. This can be done in the ways indicated above or in other ways. Besides the look-up table, a stored software program with a routine dedicated to that predetermined-set function in the C is another preferred embodiment. When the program routine selected is executed, the C can send out a digital signal to a digital-to-analog (D/A) converter to control an active circuit in the electrosurgical instrument to generate the specified waveform and its 15 power level. One way of doing this has already been described above in connection with Figs. 1-7. In summary, in this embodiment, the impedance in the smart electrode handpiece will output a control signal in the form of a different potential or voltage detected by a sensing circuit within the electrosurgical generator. The voltage is the signal to inform the C to fetch the pre-set function from ROM or in the software program, and then to execute the function. The receiving circuit in the instrument merely functions to read in the voltage or current change caused by the impedance and pass 20 it on to the A/D converter for subsequent processing.

25 [0059] As described above, the table can be a look-up table stored in a ROM chip, or can be software routines in the :C. Each record or routine represents each impedance which corresponds to a specific pre-set function. However, the pre-set functions are not limited to the listed functions in the table. They can also include radio frequency applications, a temperature controller, timing duration, hertz stimulation, ultrasonic levels, and other sorts of output signals.

30 [0060] It is preferred that the electrosurgical instrument contains "AUTO" and "MANUAL" modes. The electrosurgical instrument will select the pre-set function automatically when "AUTO" mode is selected. Otherwise, in "MANUAL" mode, the user gets the freedom to override the AUTO function and manually select a desired output waveform and its power level. Also, if the user desires, s/he may program the electrosurgical instrument to set or store this particular selection into the C memory.

35 [0061] It is preferred that the selected function be confirmed to the physician after the selection has been made in the same way that happens upon MANUAL selection, namely, the instrument will display the pre-set function on the display panel to inform the user of its current mode and output setting.

40 [0062] Fig. 13 is a block diagram illustrating one form of program for activating the MANUAL or AUTO mode of the instrument. The electrosurgical unit is at its initial state - standby mode 200 - waiting for instruction from its terminal connector connected to the selected handpiece. The electrosurgical unit will sense from the control signal inputted by a handpiece button press whether AUTO or MANUAL has been selected. For example, one button of the handpiece can be dedicated to the MANUAL mode. Alternatively, if a look-up table is employed, one record selected can have only a single data item which tells the instrument that MANUAL mode has been selected. If it is MANUAL 202, then, the unit will adjust itself to the MANUAL mode 204 for further instructions from its front panel. If AUTO has been selected, the program takes the left branch to block 206 to process further inputs from the handpiece. If an improper selection 45 208 is made, the program returns to waiting block 206. When a selection has been made by a correct button press, the program branches to the routine 210 that reads the control signal and in block 212 compares the choices made against the values stored in the look-up table for validity. If, for example, too much power was indicated, the program branches to the left branch 214 and then to a routine 216 that attempts to make an appropriate adjustment. If this is impossible, the program returns to the waiting block 206 for another input. The improper input can be displayed to the user at block 218. If the signal is OK, the program takes the right branch which sets the correct instrument mode and sub-mode and prepares 220 to deliver the selected electrosurgical currents to the electrode attached to the handpiece. At the same time, the current modes and power setting can be displayed to the user via block 222.

50 [0063] The signal confirmation or validity check made at block 212 is present to control and enable the pre-set output power block 220. This is an important safety feature of this invention. Double-checking the pre-set output power ensures the quality and quantity of output power signal to be delivered for the procedure. This will reduce or prevent any problems from a component fault in the instrument or any uncertainty of the output power. If the confirming signal is not received, the output power port will disable the power output.

55 [0064] Several examples to illustrate how specific procedures determine the operating mode are as follows:

- I. The procedure for treating telangiectasia (the light facial spider veins located on the facial, eye or nose areas.). The correct waveform for this procedure with the instrument described in the referenced patent is the partially rectified waveform, i.e., the Coagulation mode and Hemo submode. The preferred power setting is 1 or $\frac{1}{2}$ watt.

The preferred time is 1/20 of a second. The preferred electrode is a fine wire or needle.

II. Section Surgery-The correct waveform for this procedure with the instrument described in the referenced patent is the fully rectified waveform, i.e., the Cutting mode and Cut or Cut/Coag submode. The preferred power setting is about 10 watt. The preferred time is about 5 second. The preferred electrode is a blade or needle.

5 III. Epistaxis-The correct waveform for this procedure with the instrument described in the referenced patent is the partially rectified waveform, i.e., the Coagulation mode and Bipolar submode. The preferred power setting is about 35 watt. The preferred time is about 20 second. The preferred electrode is a bipolar forceps.

10 IV. Tonsillar Fulguration-The correct waveform for this procedure with the instrument described in the referenced patent is the spark gap type waveform, i.e., the Coagulation mode and Fulgurate submode. The preferred power setting is about 50 watt. The preferred time is about 1-2 second. The preferred electrode is a ball electrode.

[0065] Note that there are many more procedures than those used as illustrative above using electrosurgery, and the above examples were chosen merely to illustrate that each physician would have to remember the appropriate instrument settings as well as the appropriate electrodes and procedure duration times for each of these procedures 15 or make labels to secure this operational information. If the wrong current or power and timing is used, it may result in burning of tissue, scarring, or excessive bleeding.

[0066] With the system of the invention using the intelligent handpiece and a proper insulated electrode, the physician 20 simply plugs the handpiece into the instrument and goes immediately to the procedure with the confidence of precise, accurate waveform, power, and timing settings. A wide range of additional settings can, if desired, be added to those stored in the instrument.

[0067] Among the benefits of the invention are that it allows the handpiece or probe to be tissue and procedure specific. By choosing the correct handpiece, it is ensured that it will provide the precise waveform and power setting required by the chosen procedure. In addition, as another feature of the invention, the circuitry will allow the surgeon to override the settings determined by the handpiece by using the selective buttons on the instrument panel. If preferred, 25 an extra fingerwitch button can be added to the handpiece to provide this override function. This important feature is illustrated in the embodiments disclosed in connection with Figs. 14-30. In these embodiments, the handpiece is divided into two sections: a cable connector section that can be used and reused with different procedures, and a handpiece section that is unique to a particular procedure.

[0068] One form of such an electrosurgical handpiece 410 according to the invention is illustrated in Fig. 14. It 30 comprises on the right a cable connector section 412 comprising an electrical cable 414 terminating in a standard connector 416 for plugging into the complementary connectors of an electrosurgical instrument or system unit of the type shown in Fig. 1. In the typical prior art handpiece, the different electrodes have standard sized shanks so that they can all be fitted in the collet end of the handpiece. When a different electrode is needed, the surgeon or his or her assistant loosens the collet, removes the previous electrode, inserts a new electrode, and tightens the collet.

[0069] This feature of the invention is characterized by handpieces that incorporate fixed electrodes that are not 35 removable. In addition, the handpiece is constructed in two parts; a first removable handpiece section and a second cable connector section, with a family of handpiece sections having similar coupling sections allowing each of them to be connected to the cable connector section as desired. In other words, it is not the electrode that is removable and interchangeable with other electrodes as in the prior art that we are aware of, but rather the handpiece section that is 40 removable and interchangeable with other handpiece sections in accordance with the invention.

[0070] Referring now to the drawings, a handpiece section 418 is adapted to be fitted to and mounted to the cable- 45 connector section 412. The handpiece section 418 comprises a handle part 420 which tapers 421 toward a front end into which is permanently mounted an electrode 422 which can be any of the well known sizes and shapes of electro- surgical electrodes. Some examples are given, for example: electrode 422 in Fig. 14 is a side view of a wire or rod, and it would also be a side view of a circular curette or ring (the curette 422 is also shown from the top in Fig. 23); a 50 blade or disc 424 with a sharpened periphery shown in Fig. 27 (see US application, Ser. No. 09/819,017, whose contents are incorporated, for further details); a larger sized disc 426 shown in Fig. 28; a ball 428 shown in Fig. 29; an angled wire electrode with a sharpened point 430 shown in Fig. 30. As will be noted, the electrode can be provided with a shorter or longer shank 432 depending upon the procedure. When a curette is the electrode, it is preferred that the sharp edge faces downward and the blunt side faces upward.

[0071] The handle 420 has a triangular shape, as shown in Fig. 16. Preferably, one of the handle sides is distinguished by feel or visibly, such as by a bump or by a different color, from the other sides so that the surgeon will know the exact orientation of the electrode with respect to that one side. So in the example of Fig. 14, by providing the top side 434 with a distinguishing color 436, and assuming that the electrode is not circular symmetrical but has a significant orientation, such as if the electrode 422 were a ring, or the disc 424 of Fig. 27, and the plane of the electrode 422 is aligned with the bottom vertex 438, the surgeon knows by the position of the triangular handle 420 in his hand the orientation of the electrode 422. Other handle shapes, such as polygonal, and electrode orientations are also within the invention. 55 For example, the plane of the electrode may be aligned with a flat side of the handle or with a longitudinal ridge running

along one side of a round handle or with a longitudinal section of the handle that is differently colored. In other words, any structure or color that makes the handle non-circular symmetric can be used to inform the surgeon of the handle position in his hand relative to a particular electrode that is also non-circular symmetric. In the embodiment illustrated by the cross-section of Fig. 20, it will be noted that the widened end 459 of the body has two wide arcs 460 on opposite sides and four smaller arcs 462 between. As a result, the user using the widened end 459 can still determine electrode orientation by his hand grip on the handle.

[0072] Returning now to Fig. 14, on its right side the handpiece section 418 has an end portion 440 configured to engage for mounting and to electrically connect to the cable-connector section 412. Various shapes and structures are suitable for this purpose. A preferred construction uses a recessed male connector 442 engaging a suitably-sized recessed cylindrical female connector 444 when the two sections are engaged. The recessing of the male 442 and female 444 connectors within, respectively, a high-pressure molded electrically-insulating sheath 446 on the handpiece section and a similar molded body 448 on the cable-connector section, for example, of high-impact nylon or similar plastic, is an important safety feature to avoid personnel accidentally touching a live electrical part during the procedure. Thus, it becomes possible with complete safety for the surgeon or his assistant to switch the handpiece section 418 at any time during the procedure. Preferably, the handpiece section 418 has a widened end 450 followed by a reduced diameter section 452 which is sized for a smooth and snug fit without wobbling within a receiving section 454 at the left end of the cable-connector section (Fig. 19). When the reduced diameter section 452 engages the receiving section 454, a good electrical connection is automatically established between the female conductor 444 and the male conductor 442, which preferably is shaped as a banana plug for better contact. The molded electrically-insulating part 454 is shown alone in Fig. 18, and comprises an internal shoulder 456 and an internal screw thread 458. The banana plug 442 can be obtained with a screw base 464 which can be screwed into the internal thread 458 to secure the plug 442 in place (Fig. 19). The plug 442 has a flange that seats against the shoulder 456. While not shown in Fig. 19, in the assembly process, the bare end of the cable 414 would be soldered or otherwise secured in good electrical contact inside the plug fitting and then the wire from the left side passed through the free end of the section and assembled to the predetermined-molded body 454 until the plug screw encounters the internal thread 458 and the latter screwed together until the plug engages the shoulder 456 to securely mount the plug and cable within the electrically-insulating body 454. Afterwards, the connector 416 can be attached to the opposite cable end. So, in the case of the cable-connector section 412, its body 454 is pre-molded before the banana plug 442 and cable 414 are assembled. In the preferred case of the handpiece section 418, a metal hollow tube 470, for example, of stainless or brass, is provided (Fig. 25). It has a widened hollow end 472 which surrounds the female connector 444. An electrode 474, in this case a metal ring, is crimped hard 475 within the left end of the hollow tube 470 (see the cross-section of Fig. 21) so that a secure connection results, and then a plastic sheath 446 is injection-molded around the tube 470 as shown in Fig. 22. The crimping should be sufficiently hard to prevent the electrode from inadvertently rotating during use. The crimping is preferred as it avoids the use of solder and thus allows a stronger body to be provided by high-temperature injection molding. The entire metal tube 470 is buried within the electrically-insulating sheath 446 except for the bare electrode end 474. Note that the electrically-insulating part 446 extends beyond the right end 472 of the tube. In this case, it is preferred that the end of the body 446 adjacent the electrode 474 be oval shaped to accommodate the wider crimp 475.

[0073] In the Fig. 23 embodiment, the body 478 shape is generally round with a flat side 480 in the plane of the ring 474. In the Fig. 24 embodiment, the body 482 has a square cross-section with the plane of the ring 474 aligned with one of the vertices 484 of the square. Fig. 26 illustrates a variation 484 of the metal tube which can be oval shaped, except for the widened end 472 which is round to receive the round banana plug 442. It will be evident to those skilled in this art that other ways of providing an electrically-insulating handpiece section surrounding an electrical connector interconnecting the electrode end and the female connector end are readily devised and are also considered within the scope of the invention. These embodiments offer the advantage that it enables the handpiece manufacturer to mold a procedure-specific electrode into the handpiece thus guaranteeing the correct electrode tip, with the handpiece dictating the waveform and power setting. In this case, the electrode is fixed to the handpiece and the handpiece can only be used with that electrode in the procedure determined by its incorporated sensor component. It will also be understood that the concept of dividing the handpiece into a cable connector section and a handpiece section with or without its incorporated sensor component also can be implemented with a removable electrode.

[0074] The major benefits offered by the novel handpiece construction of the invention can be summarized as follows.

1. A simple unipolar handpiece is achieved that requires no finger switches and is easily operated by the conventional foot pedal control.
2. To implement the invention of the intelligent selection system, it is very simple to incorporate a suitable impedance or other electrical component which will generate a control signal for the electrosurgical instrument to select operating modes.
3. A family of handpiece sections is inexpensively provided each with the same configured end section 440 for engaging a common cable-connector section 412.

4. All electrical parts except for the active electrode end are shielded from accidental contact. Thus, the surgeon or assistant can easily switch electrode ends whenever desired.

5. The handle shape can be chosen for easier pressure control and navigation by the surgeon.

The assembled handpiece is lightweight allowing a light touch when applying the electrode to the patient=s tissue.

5 The orientation of the electrode can be judged without the surgeon actually viewing the electrode.

6. The low manufacturing cost of the handpiece section allows disposal after each use.

7. Color-coding or otherwise physically distinguishing the different handpiece sections will reduce the chance of physician error as a result of using the wrong electrode.

Note that there are many electrosurgical procedures using all kinds of different electrode than those used as 10 illustrative above, and the above examples were chosen to illustrate that each handpiece section can be dedicated to a particular procedure by incorporating the procedure-specific electrode permanently as part of the handpiece.

[0075] It will also be understood that the invention is not limited to the specific connectors shown. Also, different 15 shapes of the housing are also considered within the scope of the invention so long as the shape allows for easy hand holding by the surgeon and easy operation with his/her fingers of the two or more fingerswitches for mode selection if provided. In the embodiments described, a control current is supplied to the handpiece and the control signal outputted depends upon the nature of the impedance in the pressed-button circuit. As an alternative, it is also possible to include a small battery, such as a watch battery, in the handpiece, the battery supplying the DC current to be modified by the impedance in the circuit to create the control signal.

[0076] While the invention has been described in connection with preferred embodiments, it will be understood that 20 modifications thereof within the principles outlined above will be evident to those skilled in the art and thus the invention is not limited to the preferred embodiments but is intended to encompass such modifications.

25 Claims

1. An intelligent mode-selection system for an electrosurgical instrument comprising:
 - (a) an electrosurgical instrument capable of receiving a plurality of control signals for selecting an operating mode, each of said control signals when received by the electrosurgical instrument being capable of placing the instrument into one of a plurality of operating electrosurgical modes,
 - (b) a handpiece for connection to the instrument and comprising multiple fingerswitches and having an output,
 - (c) component means in the handpiece each connected to one of the fingerswitches for generating, when supplied with current and when a fingerswitch is activated, at the handpiece output one of a plurality of control signals, each of the control signals being associated with one of the plurality of operating electrosurgical modes,
 - (d) means on the handpiece for holding an electrode for delivering one of a plurality of RF electrosurgical currents each representative of one of the instrument's operating modes,
 - (e) means on the handpiece for outputting control signals to the electrosurgical instrument in response to the activation of the fingerswitches for selecting one of the operating modes,
 - (f) means in said instrument in response to receipt of the control signals from the handpiece for supplying to the electrode RF electrosurgical currents in the selected mode.
2. An intelligent selection system for an electrosurgical instrument as claimed in claim 1, further comprising a micro-controller for controlling the instrument and a storage system in the electrosurgical instrument, said storage system being capable of storing preset information representative of each of the plurality of operating modes and in response to any one of the control signals outputting control information, said microcontroller in response to the control information controlling the instrument such that the instrument is placed in the operating mode associated with the activated fingerswitch.
3. The intelligent selection system according to claim 2, wherein the storage system comprises a look-up table connected to the microcontroller, the control signal representing a key to one of plural records in the look-up table, each of the records representing an operating mode of the electrosurgical apparatus.
4. An intelligent selection system for an electrosurgical instrument as claimed in claim 1, further comprising a micro-controller for controlling the instrument in the electrosurgical instrument and software for controlling the microcontroller, said software being capable of executing preset routines representative of each of the plurality of operating modes and in response to any one of the control signals controlling the operation of the microcontroller such that that routine is executed that places the instrument in the operating mode associated with the activated fingerswitch.

5. An intelligent selection system for an electrosurgical instrument as claimed in claim 1, wherein each operating mode produces a selected one of cut, cut/coag, or hemo electrosurgical currents to the electrode, and/or a selected one of a plurality of electrosurgical current output powers to the electrode, and/or a selected one of a plurality of time durations of electrode currents to the electrode.

10. 6. An intelligent selection system for an electrosurgical instrument as claimed in claim 1, further comprising a family of handpieces each comprising an electrode integral with the handpiece, the electrode of each handpiece being customized for performing particular medical procedures, means in said instrument in response to receipt of the control signals from each of the handpieces of the family for supplying to the integral electrode RF electrosurgical currents in a selected mode customized for the procedure for which the handpiece is customized.

15. 7. A intelligent selection system according to claim 1, wherein the currents supplied to the component means are DC currents, or AC currents at a lower frequency than that of the RF electrosurgical currents, and the component means comprises different small impedances.

20. 8. A handpiece for connection to electrosurgical apparatus and comprising fingerswitches for selectively providing cutting mode or coagulation mode electrosurgical currents from the electrosurgical apparatus to an electrode connected to the handpiece, said handpiece comprising:

- (a) a pencil-like housing,
- (b) at least first and second fingerswitches on the housing,
- (c) means on the housing for receiving and holding an electrode for delivering RF electrosurgical currents,
- (d) means connected to the housing for supplying a control DC or AC current to the fingerswitches,
- (e) means connecting the fingerswitches such that when the first fingerswitch is activated a first DC or AC current level is established and when the second fingerswitch is activated a second DC or AC current level is established,
- (f) said first and second DC or AC current levels being usable to select an operating mode of the electrosurgical apparatus.

30. 9. A handpiece according to claim 8, further comprising an electrical connector comprising three terminals and connected at a side of the housing, one of the three terminal being connected to the electrode and the other two of the three terminals being connected to the fingerswitches, the first and second current levels being available at the same connector terminal.

35. 10. A handpiece according to claim 8, further comprising an electrode fixed to the handpiece, the electrode being associated with the selected operating mode.

40. 11. A handpiece according to claim 8, further comprising a non-volatile read/write memory in the handpiece, said memory storing data items representing operating modes of the electrosurgical apparatus.

45. 12. A handpiece according to claim 8 for connection to electrosurgical apparatus for providing one of cutting mode or coagulation mode electrosurgical currents from the electrosurgical apparatus to the electrode, the electrode being adapted for use in a specific electrosurgical procedure, the control current representing for the electrosurgical apparatus operating mode information associated with the specific procedure and usable by the electrosurgical apparatus to select an operating mode specific to the procedure.

50. 13. A handpiece for an electrosurgical instrument comprising:

- (a) a handpiece section having at one end a mounting portion configured to removably engage for mounting and for electrically connecting to a complementary part of a cable-connector section,
- (b) an electrode permanently connected to the opposite end of the handpiece section,
- (c) a cable-connector section for connection to the instrument, the cable-connector section having at one end a receiving portion for removably receiving the mounting portion of the handpiece section.

55. 14. A handpiece for an electrosurgical instrument as claimed in claim 13, wherein the cable-connector section further comprises a cable and a connector for connecting to the instrument.

15. 15. A handpiece for an electrosurgical instrument as claimed in claim 13, wherein the cable-connector section com-

prises a molded electrically-insulating body having on its interior one of a male and female electrical connector.

- 5 16. A handpiece for an electrosurgical instrument as claimed in claim 15, wherein the handpiece section comprises a molded electrically-insulating body having on its interior the other of the male and female electrical connector, the male and female electrical connectors having complementary shapes for electrical engagement when the handpiece section mounting portion engages the cable-connector section receiving portion.
- 10 17. A handpiece for an electrosurgical instrument as claimed in claim 16, wherein the handpiece section mounting portion comprises a cylindrical portion and the cable-connector section comprises a hollow cylindrical portion adapted to snugly receive the handpiece section mounting portion.
- 15 18. A handpiece for an electrosurgical instrument as claimed in claim 17, wherein the handpiece section mounting portion comprises a female connector and the cable-connector section comprises a male connector, and the female connector and the male connector are each recessed within the electrically-insulating body of their respective section.
- 20 19. A plurality of handpieces as claimed in claim 13 constituting a family, each member of the family comprising an electrode permanently connected to the opposite end of each of the handpiece sections, the electrodes being differently shaped or sized in each member of the family, the cable-connector section having at one end a common receiving portion for removably receiving each of the mounting portions of each of the handpiece sections of each family member.
- 25 20. The handpieces as claimed in claim 19, wherein each of the handpiece section=s body is physically configured or labeled or colored to indicate to a user a specific procedure for which the electrode is adapted.
21. A handpiece as claimed in claim 13, wherein the handpiece section is free of electrical wires or cables or connectors for connecting to the electrosurgical instrument.
- 30 22. A handpiece as claimed in claim 21, wherein the handpiece section=s body is physically configured to indicate to a user the orientation of the electrode.

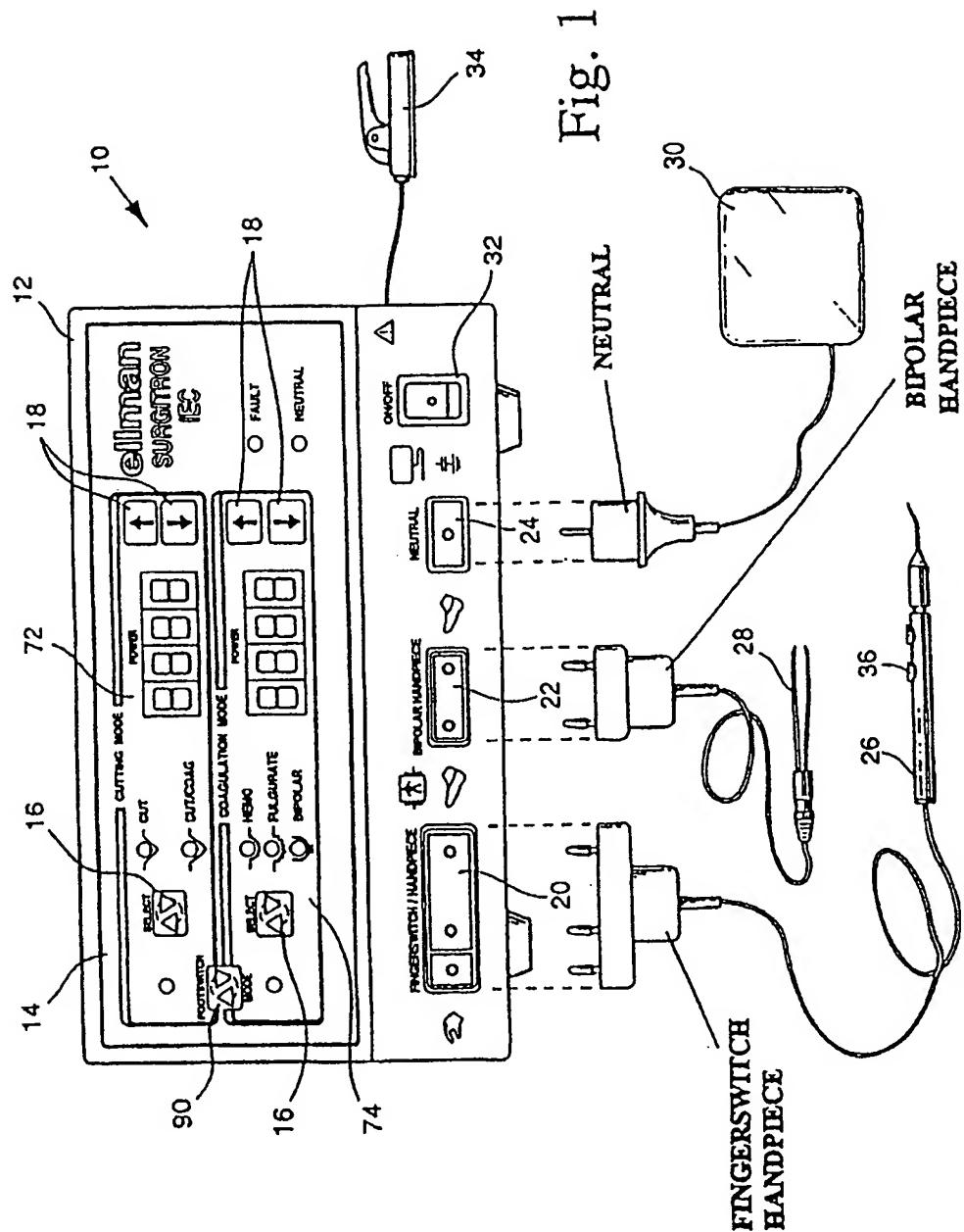
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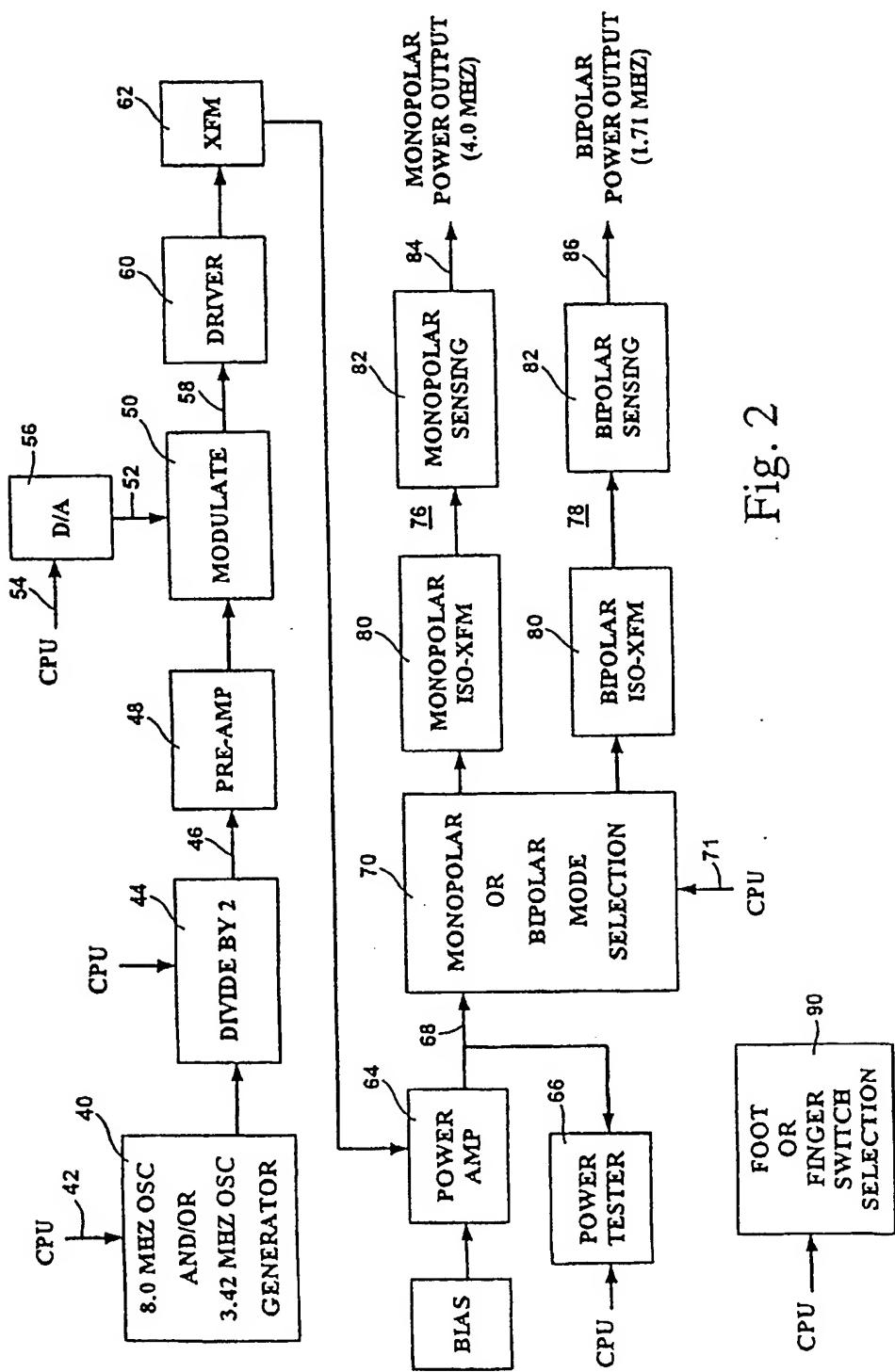


Fig. 2

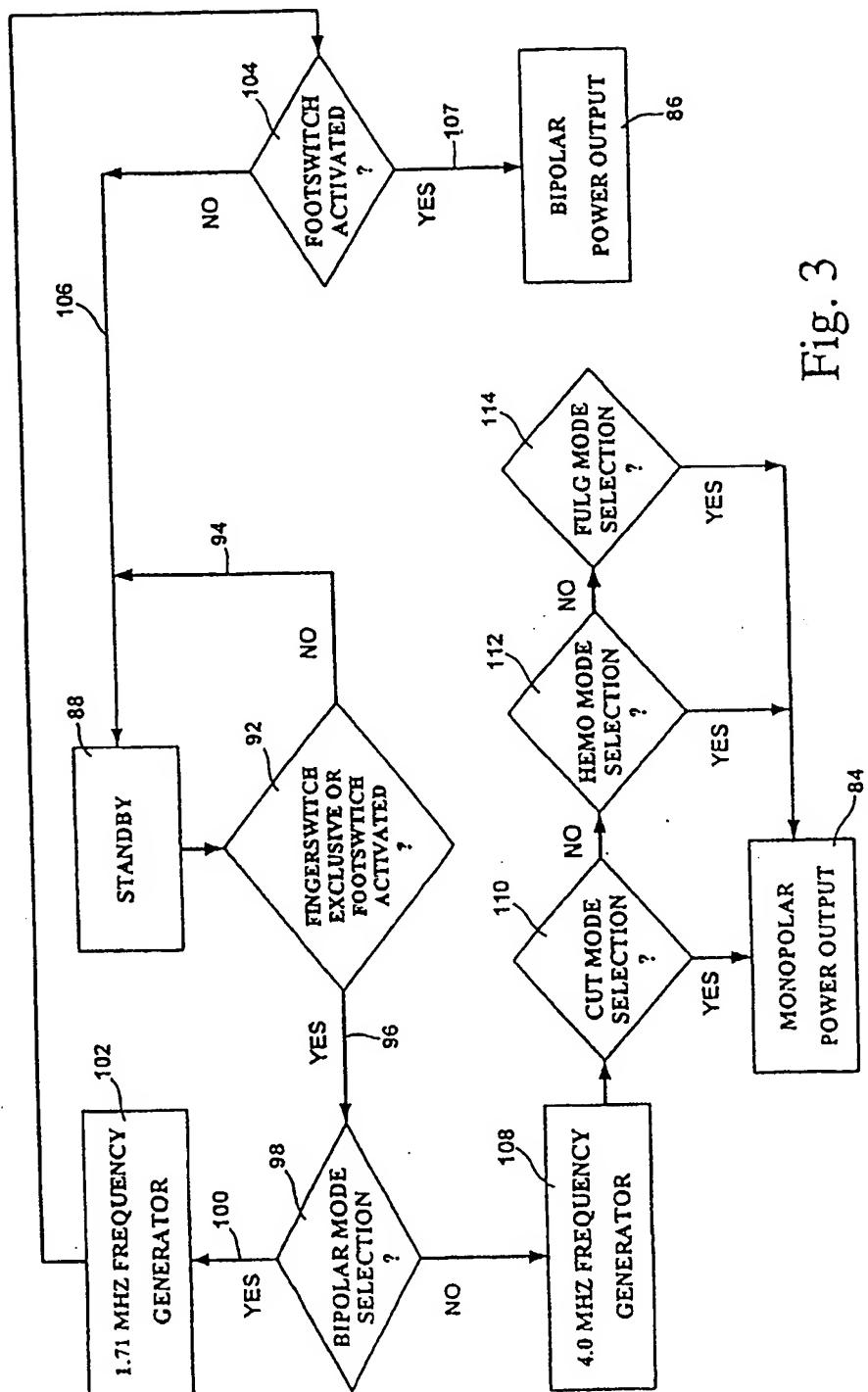


Fig. 3

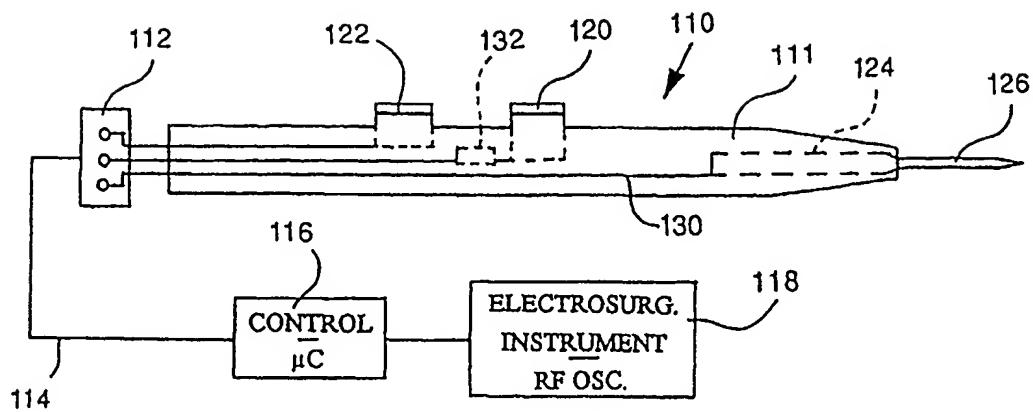


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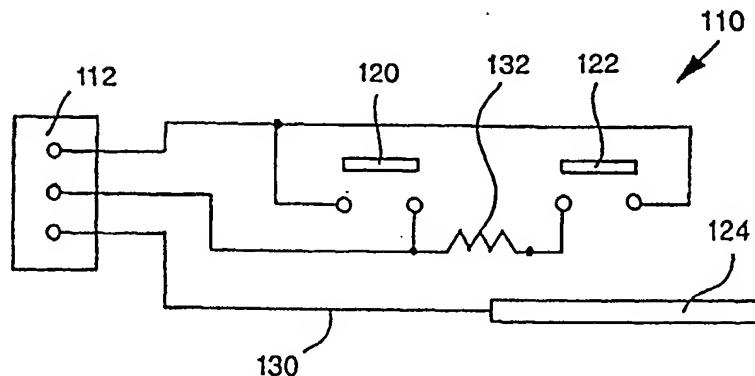


Fig. 5

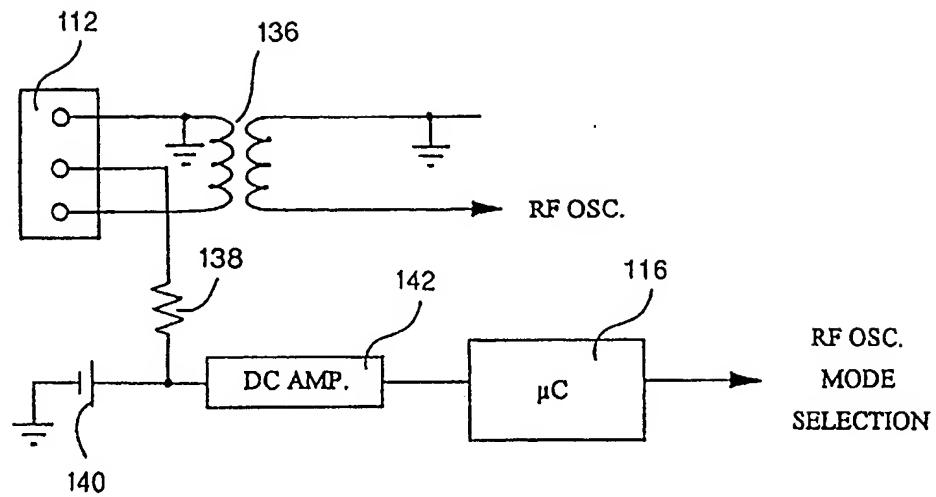


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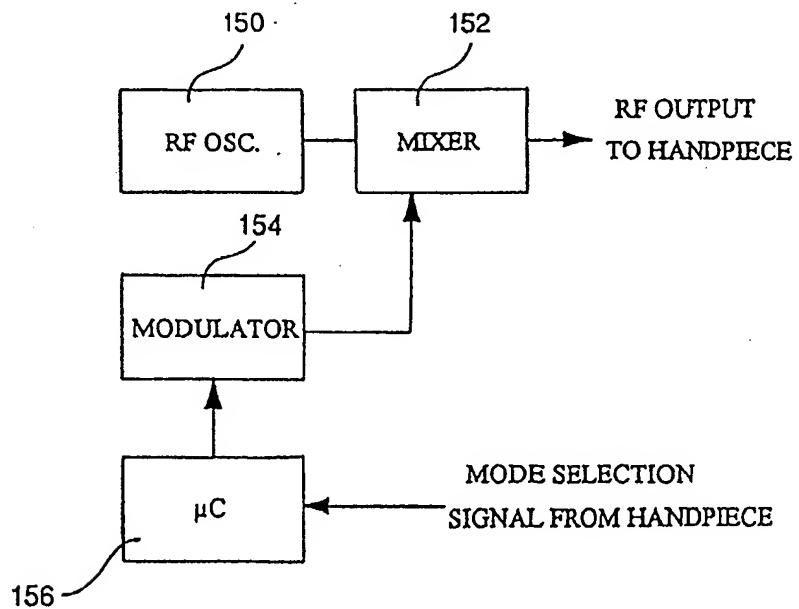
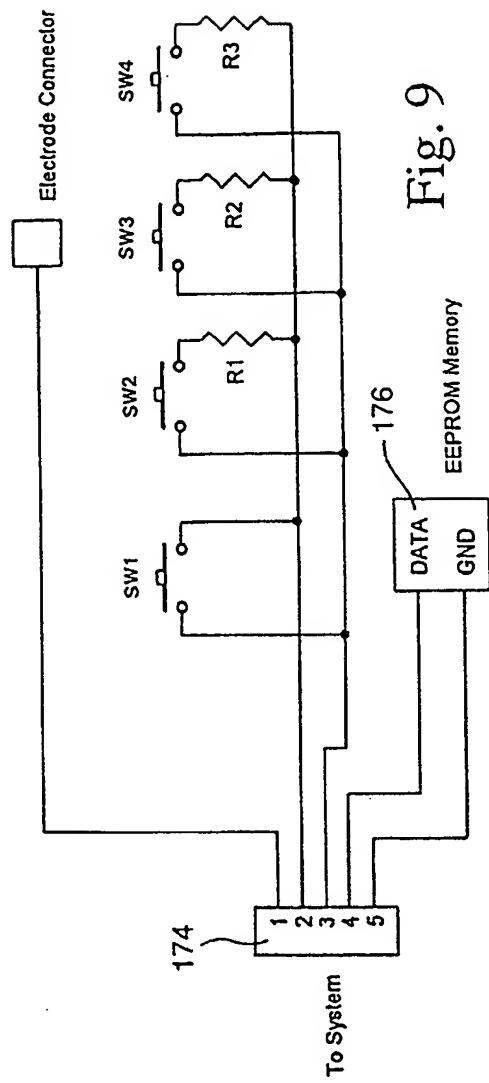
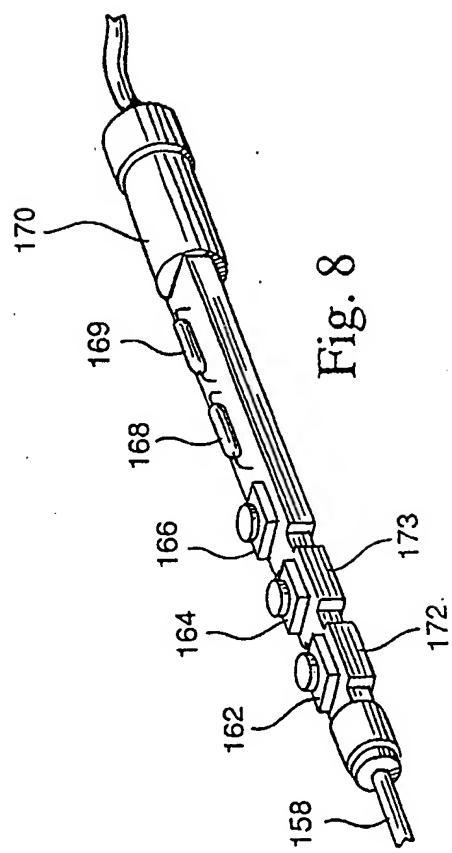
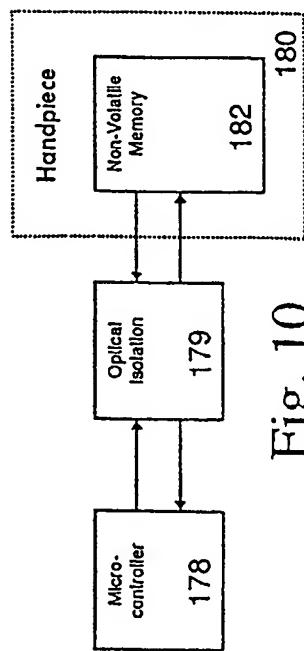
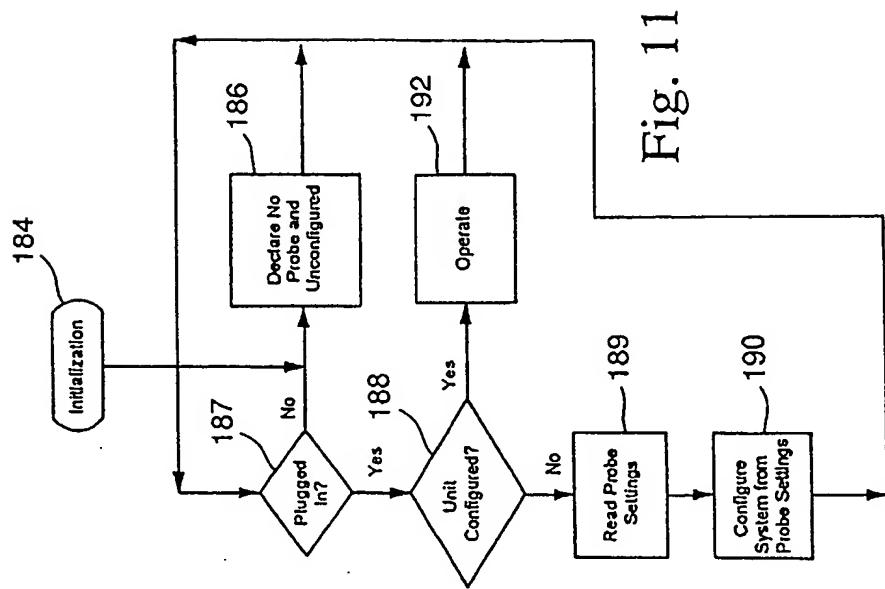


Fig. 7





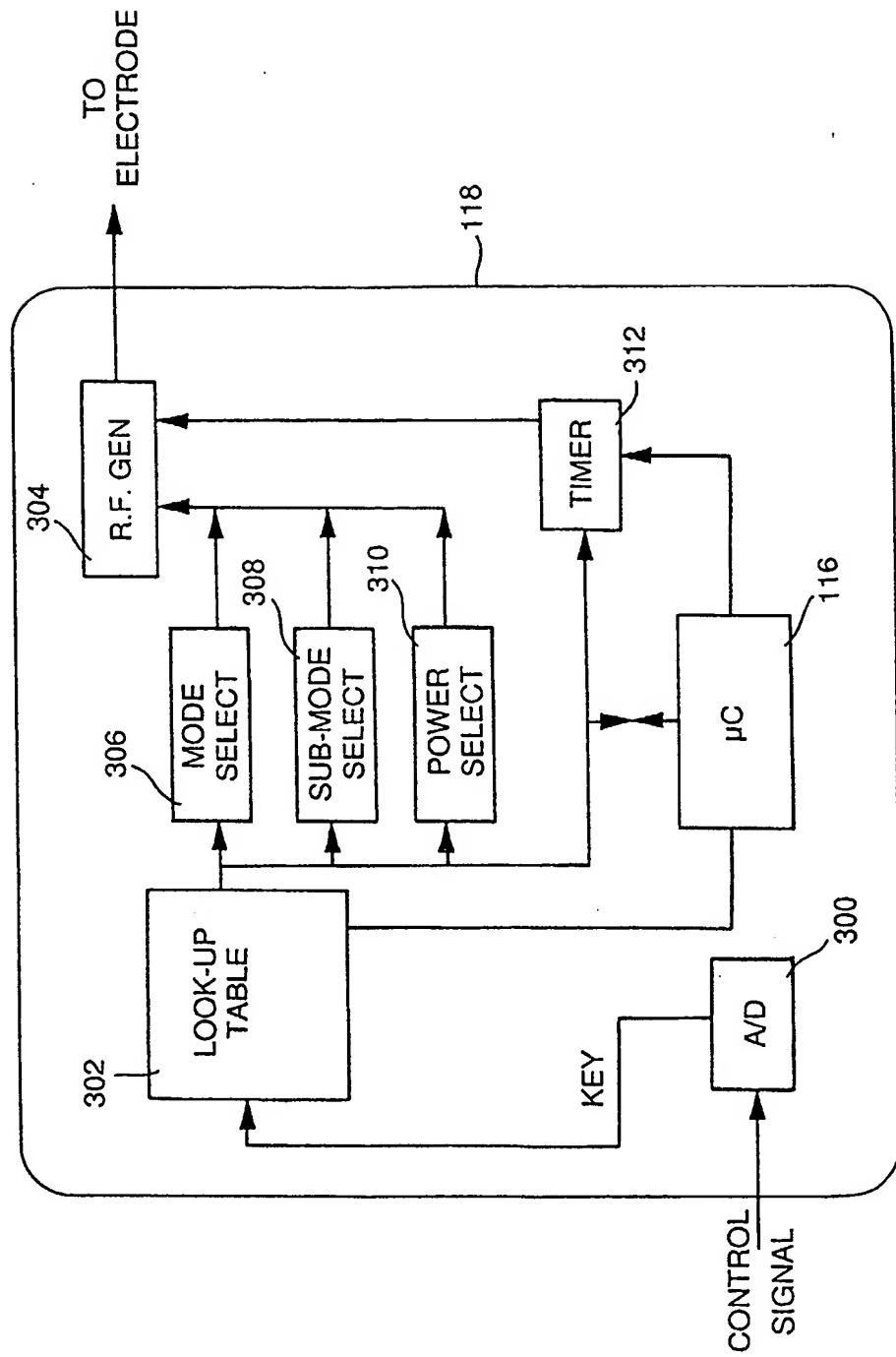


Fig. 12

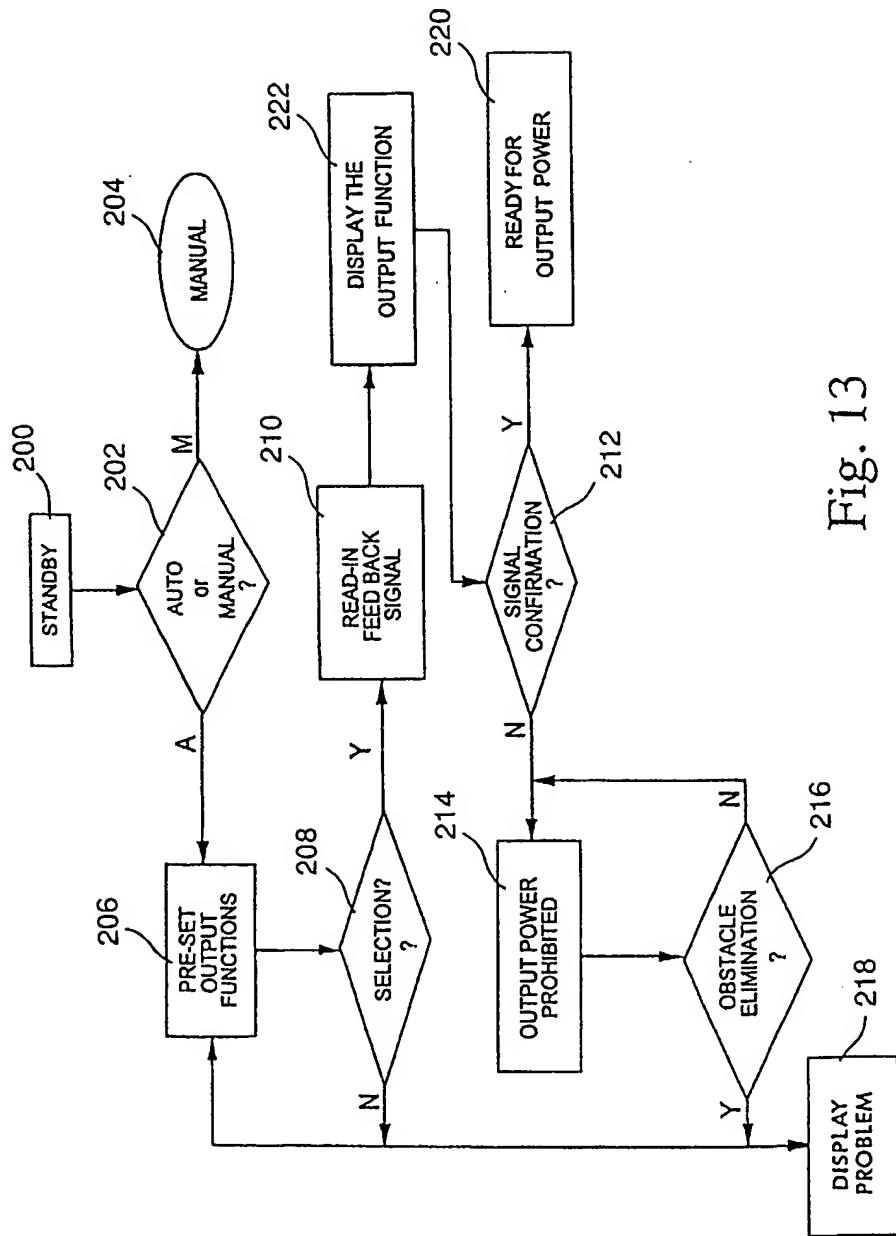


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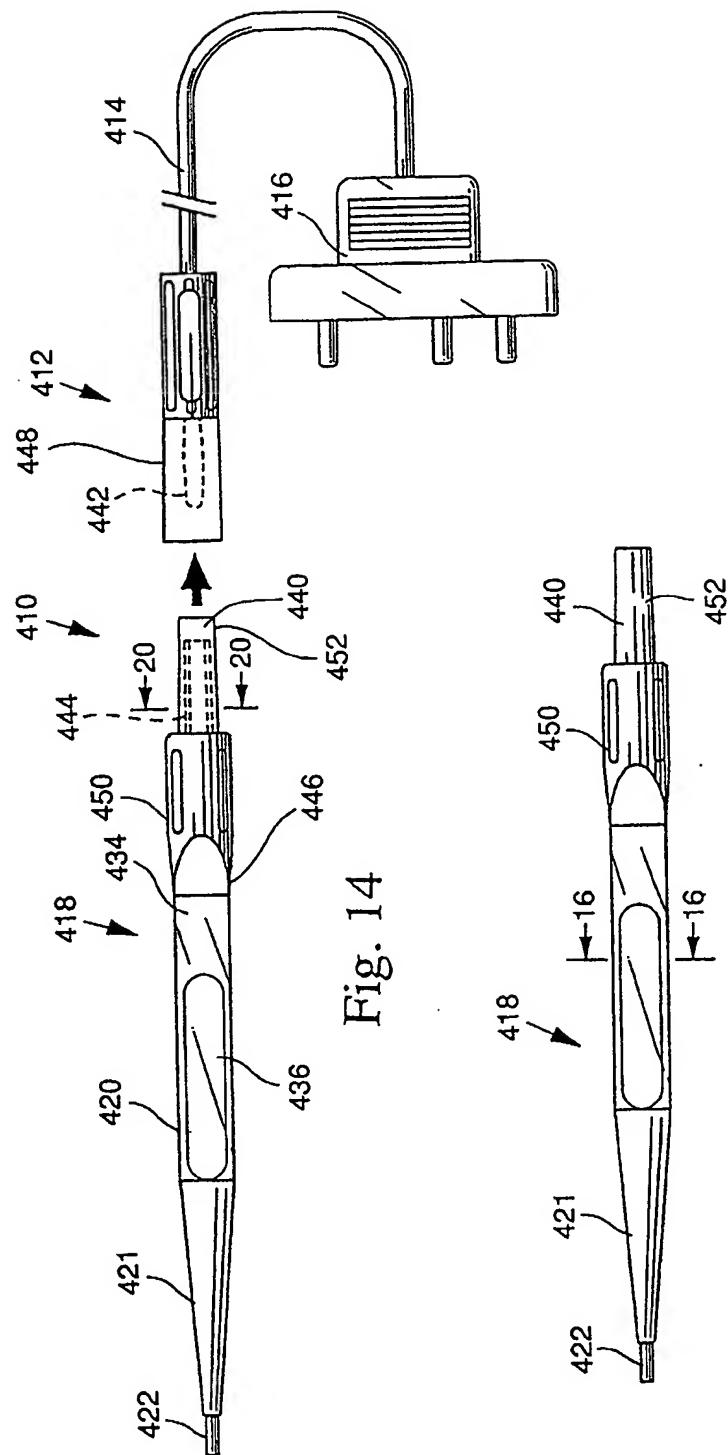


Fig. 14

Fig. 15

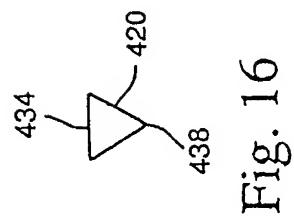


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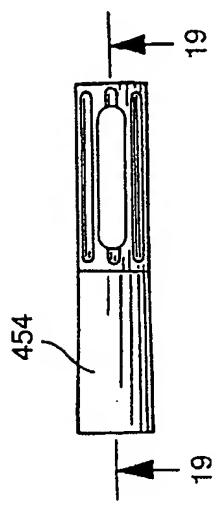


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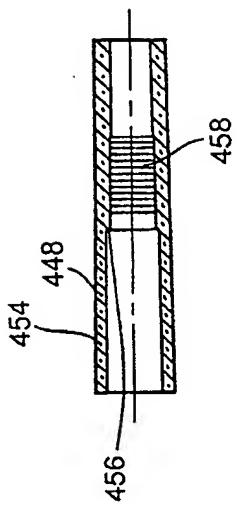


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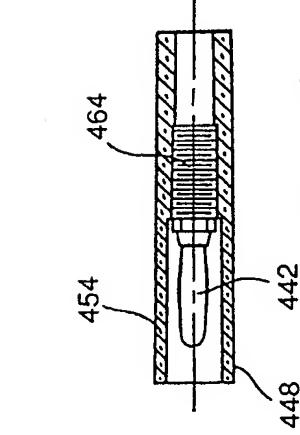


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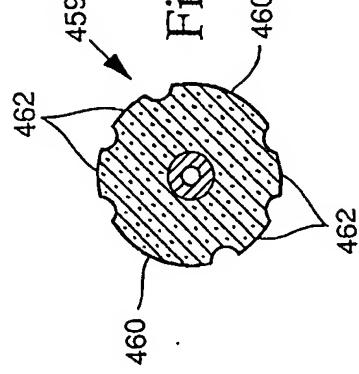


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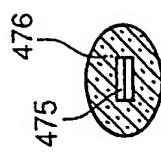


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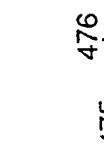


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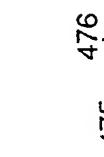


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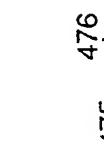


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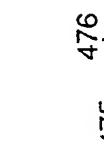


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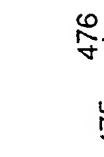


Fig. 26

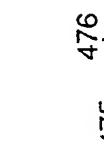


Fig. 27

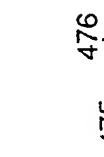


Fig. 28

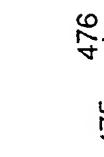


Fig. 29

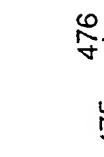


Fig. 30

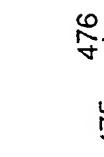


Fig. 31

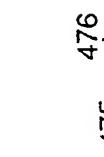


Fig. 32

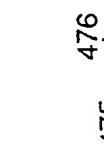


Fig. 33

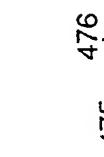


Fig. 34

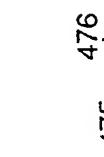


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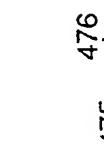


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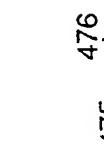


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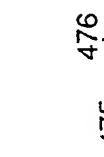


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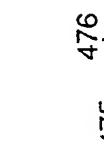


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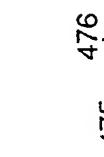


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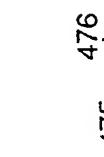


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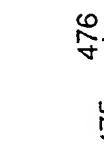


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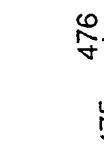


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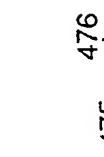


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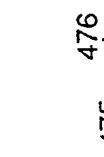


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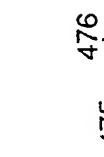


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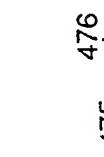


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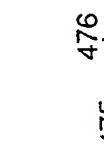


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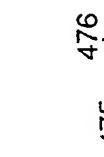


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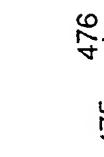


Fig. 50

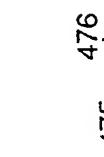


Fig. 51

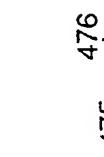


Fig. 52

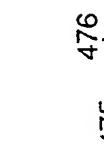


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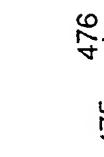


Fig. 54

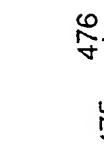


Fig. 55

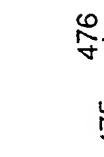


Fig. 56

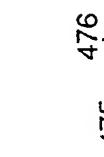


Fig. 57

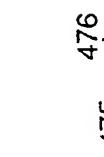


Fig. 58

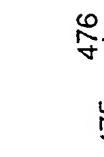


Fig. 59

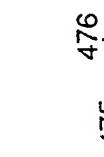


Fig. 60

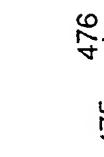


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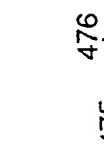


Fig. 62

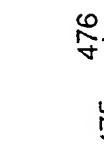


Fig. 63

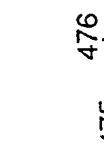


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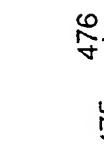


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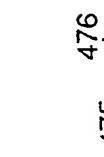


Fig. 66

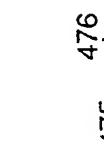


Fig. 67

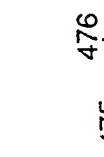


Fig. 68

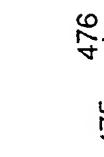


Fig. 69

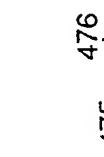


Fig. 70

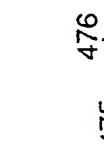


Fig. 71

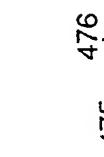


Fig. 72

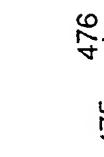


Fig. 73

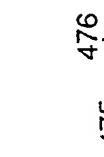


Fig. 74

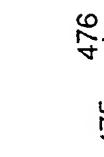


Fig. 75

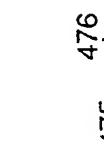


Fig. 76

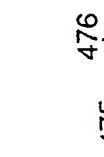


Fig. 77

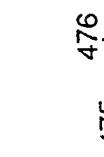


Fig. 78

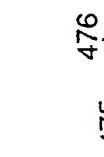


Fig. 79

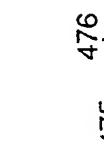


Fig. 80

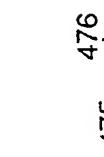


Fig. 81

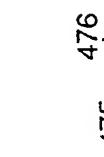


Fig. 82

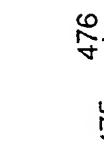


Fig. 83

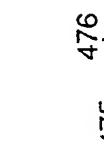


Fig. 84

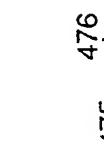


Fig. 85

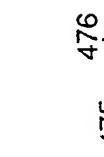


Fig. 86

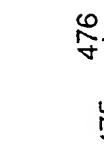


Fig. 87

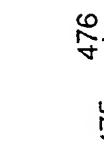


Fig. 88

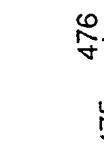


Fig. 89

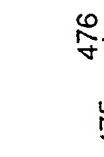


Fig. 90

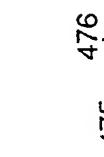


Fig. 91

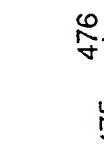


Fig. 92

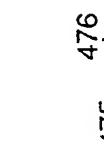


Fig. 93

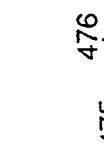


Fig. 94

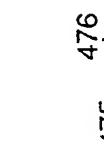


Fig. 95

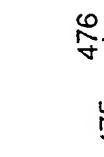


Fig. 96

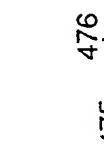


Fig. 97

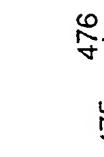


Fig. 98

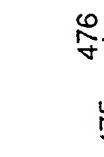


Fig. 99

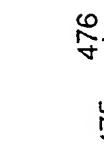


Fig. 100

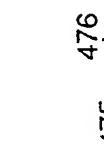


Fig. 101

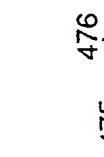


Fig. 102

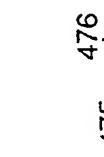


Fig. 103

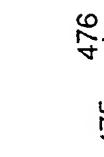
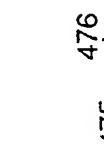


Fig. 104



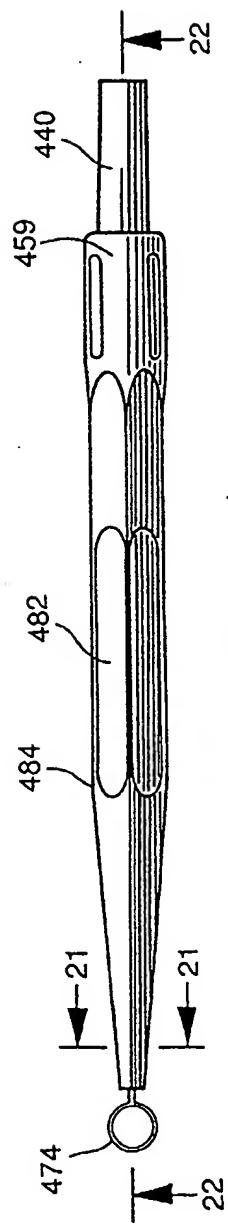
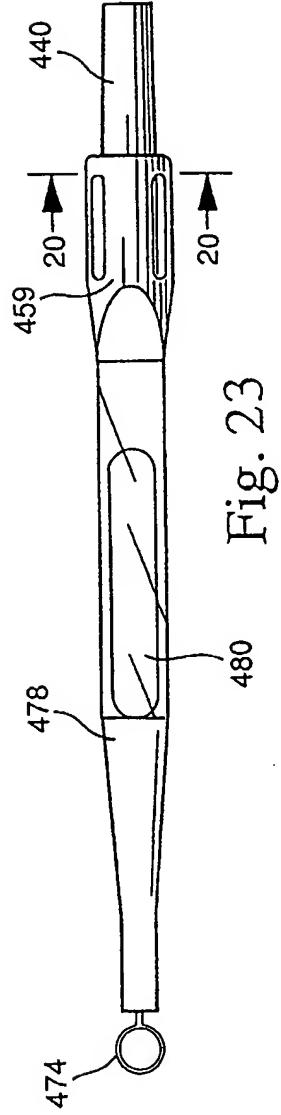
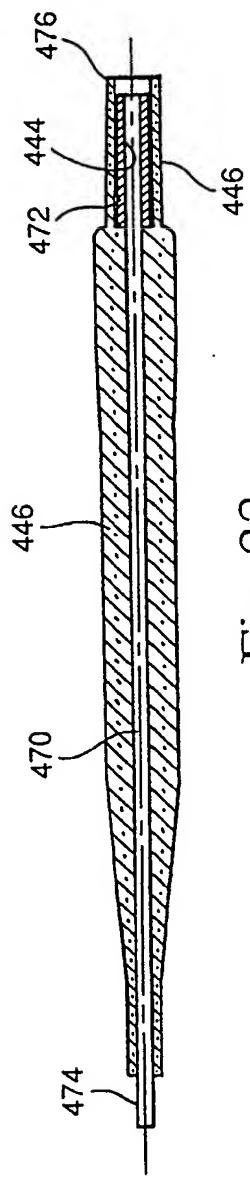




Fig. 25

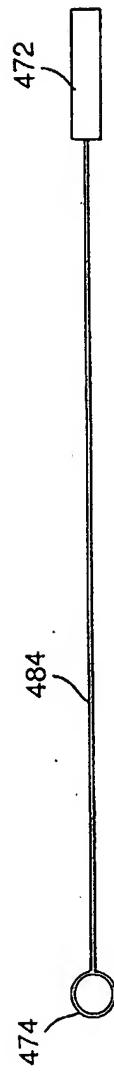


Fig. 26

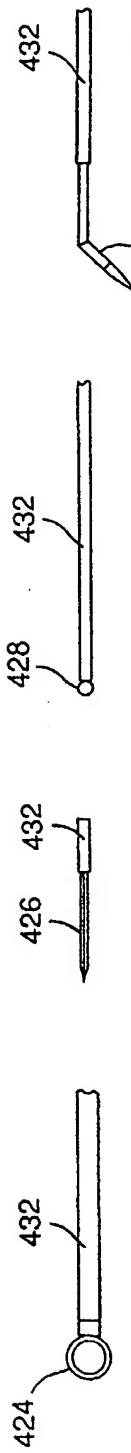


Fig. 27

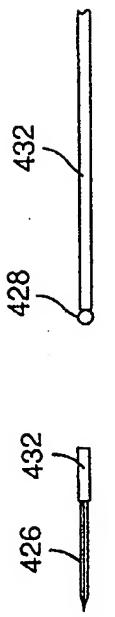


Fig. 28

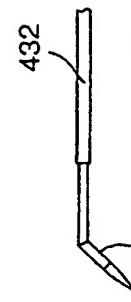


Fig. 29

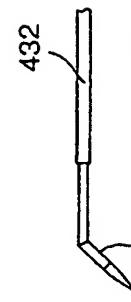


Fig. 30

(19)



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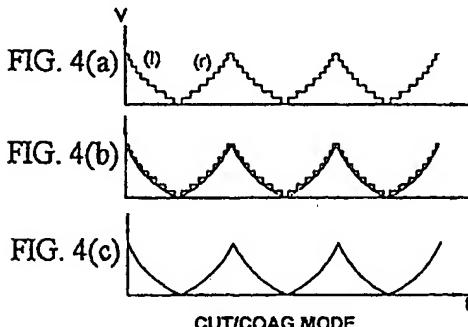
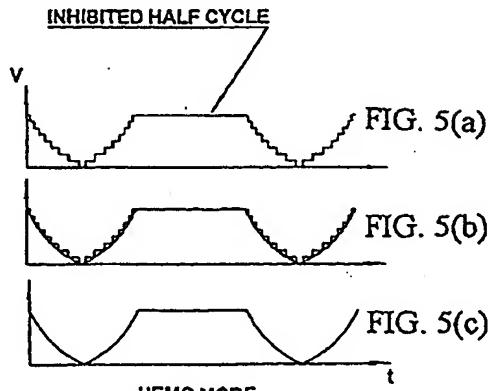
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(54) Low-voltage electrosurgical apparatus

(57) Low-power, low-voltage electrosurgical apparatus providing three current unipolar modes whose circuitry for generating the modulation signals needed to implement the three current modes employs no microcontroller but generates the modulation waveforms using a oscillator-binary counter and dual multiplexers, integrated components (ICs) that are of relatively low cost. Safety features can be incorporated by including a timer circuit cooperating with the binary counter to provide power to the IC components and avoid overheating of the apparatus. The oscillator-binary counter component is used to generate at plural outputs plural series of digital pulses at various frequencies, some of the pulse series being used to generate approximate sine-waves that can be employed for the cut/coag and hemo modes, and others of the pulse series being employed to operate a timer, indicator lights, and an audible warning system.



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Description

[0001] The invention is directed to an electrosurgical instrument or apparatus, and in particular to an electrosurgical instrument that operates with a lower output voltage and a lower output power.

BACKGROUND OF INVENTION

[0002] Electrosurgical instruments are well known and widely used in the medical, dental, and veterinarian fields. They offer the capability of precision cutting with electrosurgical currents in the megacycle range using a handpiece with needle, ball, or loop electrodes in a unipolar operating mode, or convenient coagulation using a forceps in a bipolar operating mode. Ellman International, Inc. makes available an electrosurgical instrument, Model FFPF, which provides on its front panel connectors for receiving the plug of a unipolar handpiece and a ground or indifferent plate, as well as connectors for receiving the plugs of a bipolar forceps.

[0003] There are environments in which the electrosurgical apparatus has to satisfy stringent requirements, including but not limited to simple operation, low cost, energy efficient, safe, and user friendly. In addition, it should provide the capability of precision cutting, coagulating, and homeostasis using high radio-frequency (RF) electrical current, preferably of the order of 3.5-4 mHz, with 4 mHz being preferred.

[0004] We have found that most of these requirements can be satisfied with low power electrosurgical apparatus that includes only unipolar capability provided that the output power is kept low, preferably at or below about 50 watts. The Model FFPF, whose principles are described in some detail in USP 3,730,188 ('88), and further in USP 4,463,759 ('79), the contents of both of which are fully incorporated herein by reference, had an output of about 100 watts. Moreover, the Model FFPF used electron tubes, which required high voltages to operate and limited the number of user-friendly features that could be incorporated. Other commercial electrosurgical apparatus, also of the high-voltage, high-power type, employed programmable microcontrollers for producing the different current waveforms needed for surgical tissue cutting, for simultaneous cutting and coagulation, and for coagulation (hemostasis) alone, commonly referred to as the cut, cut/coag, and hemo modes, respectively. USP 3,730,188 illustrates in Figs. 5a, 5b and 5c the three modes above described. As will be noted, the cut mode current waveform is a fully-rectified, fully-filtered, continuous wave (CW) carrier at the RF frequency; the cut/coag mode current waveform is a fully-rectified, unfiltered, continuous wave (CW) carrier at the RF frequency; and the hemo mode current waveform is a half-wave rectified, unfiltered, continuous wave (CW) carrier at the RF frequency. The cut/coag and hemo mode currents are commonly referred to as modulated RF cur-

rents. The commercial electrosurgical apparatus of the high-voltage, high-power type employing microcontrollers also are more complex, require more electronic components and assembly, and are thus more expensive than the Model FFPF.

SUMMARY OF INVENTION

[0005] A principal object of the invention is an electrosurgical apparatus capable of providing optimal RF energy for the three unipolar modes described above but manufacturable at a lower cost.

[0006] Another object of the invention is an electrosurgical apparatus capable of providing optimal RF energy for the three unipolar modes described above but characterized by lower output voltage and power.

[0007] Still another object of the invention is an electrosurgical apparatus capable of providing optimal RF energy for the three unipolar modes described above but manufacturable at a lower cost yet providing many user-friendly features without the use of a microcontroller.

[0008] These objects are achieved in accordance with one aspect of the invention by an electrosurgical apparatus whose circuitry for generating the modulation signals needed to implement the three current modes employs no microcontroller but generates the modulation waveforms using an oscillator-binary counter and dual multiplexers, integrated components (ICs) that are of relatively low cost.

[0009] In accordance with another feature of the invention, safety features can be incorporated by including a timer circuit cooperating with the binary counter to provide power to the IC components and avoid overheating of the apparatus.

[0010] A feature of the invention is to use the oscillator-binary counter component to generate at plural outputs plural series of digital pulses at various frequencies, some of the pulse series being used to generate approximate sine-waves that can be employed for the cut/coag and hemo modes, and others of the pulse series being employed to operate the timer, indicator lights, and an audible warning system. Thus, many functions are performed by the circuit components thereby minimizing the component count and reducing costs.

[0011] Electrosurgical apparatus according to the invention is capable of providing high-quality RE energy at a 3.5-4 mHz frequency best suited for delicate, precise, and quick-healing cutting procedures with low leakage currents using a unipolar handpiece, as well as high-quality modulated RF energy best suited for hemostasis with the unipolar handpiece. In addition, its output RF frequency remains substantially unchanged irrespective of load changes. Moreover, it will provide a controlled duty cycle, i.e., relative times that the RF currents are delivered to a patient versus the times that delivery is interrupted, a feature that was not possible

with the Model FFPF.

[0012] The various features of novelty which characterize the invention are pointed out with particularity in the claims annexed to and forming a part of this disclosure. For a better understanding of the invention, its operating advantages and specific objects attained by its use, reference should be had to the accompanying drawings and descriptive matter in which there are illustrated and described the preferred embodiments of the invention, and in which like reference numerals denote the same or similar components.

BRIEF DESCRIPTION OF DRAWINGS

[0013]

Fig. 1 is a block circuit diagram of one form of electrosurgical apparatus according to the invention; Fig. 2 is a schematic circuit illustrating how the modulation waveforms are obtained; Fig. 3 illustrates parts of a sine-wave to be used to generate the modulation waveforms; Figs. 4(a), 4(b) and 4(c) illustrate how a fully rectified half sine-wave modulation waveform can be obtained for one operating mode; Figs. 5(a), 5(b) and 5(c) illustrate how a half rectified half sine-wave modulation waveform can be obtained for a different operating mode.

DETAILED DESCRIPTION OF PREFERRED EMBODIMENTS

[0014] Electrosurgical apparatus according to the invention is a high frequency, low power output, low-output voltage, all-solid-state electrosurgical apparatus. The construction is unique, simple, energy efficient, safe, and user friendly. It provides the essential operational modes that are most often used in electrosurgical applications. In a preferred form, the unit has a maximum 50 watt output power and provides the capability of precision cutting, coagulating, and homeostasis using, preferably, 4 mHz frequency electrosurgical currents.

[0015] One form of an electrosurgical apparatus according to the invention comprises several functional interconnected stages as shown in the circuit block diagram of Fig. 1. There are four major functions to be performed; power supply, modulating signal generator, RF generator, and signal modulation, patient isolation and matching. The power supply, RF generator, and signal modulation, patient isolation and matching can for purposes of this application be considered conventional, since any conventional voltage-regulated, RF filtered, stable power source can be substituted, any stable, reliable 4 mHz RF generator can be substituted, and typical patient isolation is accomplished by an output transformer whose secondary is coupled by way of a matching network to the active lines going to the elec-

tosurgical handpiece and neutral plate. The impedance matching network matches the source impedance to the range of patient impedance. The output power is referenced to ground through an output isolation capacitor (not shown). The impedance matching circuit, which is also commonly known as the patient circuit, is completely isolated from the secondary power circuit by the isolation transformer.

[0016] The Fig. 1 block diagram includes these conventional elements to assist in understanding of the invention. The RF carrier is supplied by an RF generator 10, typically a crystal-controlled solid-state oscillator whose output is pre-amplified and then power amplified 12 for driving the RF driver 14. The RF driver may comprise, for example, a power MOS device (not shown) whose body contact is driven by the RF carrier. The MOS source is at ground potential, and its drain circuit is connected to the RF-isolated power supply via the primary of the isolation transformer 16, whose secondary is connected via the matching network 18 to the active 20 and neutral 22 outputs, the active output being accessible by the usual unipolar handpiece and the neutral being typically connected to the ground plate placed in contact with the patient.

[0017] The apparatus of the invention generates 3 waveforms to perform the cut, cut/coag, and hemo unipolar functions. These 3 are illustrated in Figs. 5a, 5b, and 5c of the referenced '188 patent, the cut waveform in Fig. 5a of the patent being the filtered unmodulated RF carrier which would be present at the output 24 of the RF driver 14 (Fig. 1) assuming the modulation is disabled. This pure 4mHz signal is sometimes referred to as the CW output. The cut/coag waveform in Fig. 5b of the patent is the full-wave rectified modulated RF carrier which would be present at the output 24 of the RF driver 14 (Fig. 1) assuming a full wave rectified modulation is applied to the modulation input 26 of the RF driver 14, for example, to the drain of the power MOS driver. The hemo waveform in Fig. 5c of the patent is the half-wave rectified modulated RF carrier which would be present at the output 24 of the RF driver 14 (Fig. 1) assuming a half-wave rectified modulation is applied to the modulation input 26 of the RF driver 14, for example, to the drain of the power MOS driver.

[0018] The modulating waveforms generator which supplies the full-wave rectified and half-wave rectified modulation is supplied from block 28 via a mode selector switch 30 which can be either a 3-position switch on the front panel of the apparatus or a switch built into the handpiece.

[0019] A feature of the invention is the use of a multi-pulse generator 32, preferably in the form of a binary counter/divider, to generate from a simple high frequency oscillator input a plurality of pulse sequences at a number of different rates or frequencies, some of which are integer multiples of each other. More specifically, the counter/divider takes an input frequency and divides it into one or more other frequencies each of

which is a predetermined fraction of the input. It typically comprises a number of cascaded flip-flop stages the output frequency of each of which is one-half its input frequency. These trains of pulse sequences perform many different functions, the most important of which include generation of the modulation waveforms. Essentially, the circuit uses digitally controlled analog switches which connect a selected pin to a common output pin. The common output pin of each is connected to a power source through one of a chain of external voltage dividers. Successive selection of the analog switches provides a digital-to-analog function to generate one half of the desired sine function. The waveform shape is determined by the relative values of the resistors forming the voltage divider, while the second half of the half sine-wave is formed by another multiplexer using the same resistors in reverse order. One multiplexer provides a decreasing stepped voltage starting from a maximum voltage of the sine-wave while the other provides an increasing stepped voltage starting from the minimum of the sine-wave. The steps are the same for both. Address selection of the selected pin (channel) of the multiplexors is generated from the oscillator/divider. The divider chain, in conjunction with the oscillator/divider, switches the two multiplexers ON and OFF to generate the downward and upward slopes of the half sine-waves. A further frequency selected by the mode selector inhibits every other half sinusoid to generate the hemo waveform.

[0020] One form of this digitally-controlled analog switch is illustrated in Fig. 2. A binary counter/divider 34 may be an off-the-shelf component, for example, the CD4060B IC, a CMOS 14-stage ripple-carry binary counter/divider with a built in oscillator. The oscillator designated 36 is shown as a separate component, as it can be separately provided if desired, but is actually included in this particular IC. The oscillator 36 with the addition of suitable RC components generates at its output 38, for example, a 37kHz signal. While examples will be given of operating frequencies to better illustrate operation, it will be understood that the invention is not limited to those particular frequencies. The ripple-carry binary counter/divider 34 generates at its output 40 from the 37kHz source a number of trains of pulse sequences at lower frequencies which are integer divisors of one another (integers will be used in the examples for simplicity, but it will be understood that, since binary division is involved, each of the signals are in fact exact integer multiples even though the example numbers given appear slightly off); for example, 72, 146, 290, and 580 Hz are multiples of 2 of the preceding number in the sequence. "Integer divisors" is used herein to mean each number of a series differs from the other numbers by an integer, i.e., any lower number in the series can be obtained by dividing a higher number by an integer. The 146, 290, and 580 Hz pulse frequencies are used to create a 3 digit binary code. For example, since the three pulse sequences are integer

divisors, when all pulses have their leading edges aligned, it produces the binary code 1-1-1. When all pulses have out-of-line leading edges, it produces the binary code 0-0-0. When 2 of the pulse trains are aligned, but not the 3rd, then binary signals such as 1-1-0, or 1-0-1, or 0-1-1 are generated. As will be evident, since the pulse trains are integer multiples, a succession of 1 of 8 binary codes will be outputted 40 in sequence. The 72 Hz signal functions as an inhibit signal.

[0021] The succession of binary codes is outputted on three lines 42, 44, 46 connected in parallel to a pair of analog multiplexors 48(l) and 48 (r), for example the CD4051B IC. The inhibit signal is applied via line 50 directly to the left multiplexor 48 (l) and via an inverter 52 to the right multiplexor 48 (r). The binary code inputted connects (turns ON) 1 of 8 lines of the multiplexor pairs to a single output lead 54, which is connected to a voltage source V+ and a load resistor 55, and to 1 of 8 resistors 56 of different resistance values, chosen so that 8 successively decreasing/increasing voltage dividers (resistors 55, 56) are created and the output voltage on line 54 has a value that depends on the value of the 1 of 8 resistors to which it is connected. For simplicity, only 2 resistors 56 are shown, but the component in question has 8 outputs (hence the name 8-channel) each of which is connected to 1 of the 8 resistors 56. So, for example, when the binary code 000 is inputted via lines 42, 44, 46, the voltage on line 54 is 5 volts; when the binary code 001 is next inputted, the voltage on line 54 is reduced to 4.4 volts; when the binary code 010 is inputted, the voltage on line 54 is reduced to 3.8 volts; and so on. In this way, by connecting in succession the 8 binary codes to the left multiplexor 48 (l) inputs, the output voltage on line 54 varies in steps from 5 volts to approximately zero. This is illustrated in Fig. 3 at (l) designating the left multiplexor. This function has been carried out while the 72 Hz frequency pulse has been applied via line 50 to the inhibit input 60 of the left multiplexor 48(l). While this 72 Hz pulse is high at the inhibit input 60, the multiplexor 48(l) is enabled. The same 72 Hz frequency pulse is also applied via the inverter 52 to the inhibit input 62 of the right multiplexor 48(r). The inverter 52 inverts the high pulses to low pulses which disables the right multiplexor 48(r). When the 72 Hz frequency pulse terminates, the reverse action takes place. The left multiplexor 48(l) becomes disabled and the right multiplexor 48(r) enabled, and now the output line 54 of the right multiplexor 48(r) as a result of the binary codes inputted shows an increase in voltage of the same steps but reversed to that shown in Fig. 3 at (l), which is shown in the curve labelled (r) in Fig. 3. When the voltages on line 54 are combined over the full cycle, an approximately half sine-wave is generated. This is illustrated in Fig. 4(a), which plots the voltage on line 54 as a function of time t. As will be observed, one-half (l) of the sinewave is produced by the left multiplexor 48(l) and the other half (r) by the right multiplexor

48(r) which have operated in succession as above described.

[0022] The output from the multiplexors is passed through a conventional buffer stage 64 and an RC smoothing filter 66 and the output then transmitted to the mode selector switch 30. Fig. 4(b) illustrates the effect of a smoothing filter on the output waveform, and Fig. 4(c) shows the actual sine-wave output that can be used to modulate the 4 mHz carrier for the cut/coag mode. Fig. 5(a), (b), and (c) show the corresponding outputs at just one of the enabled multiplexors when the other one is disabled. The mode selector 30 applies the desired modulating waveform to the RF driver 14. It will be evident from the foregoing that when, say, the right multiplexor 48(r) is permanently disabled, then the output at line 54 is only the half-wave rectified signal shown in Fig. 5(c). Hence, the hemo mode using the half-wave rectified signal shown in Fig. 5(c) is easily obtained by permanently disabling the right multiplexor 48(r) using a pulse frequency of 36 Hz also obtained from the binary counter/divider 34 at an additional output 66 and supplied to the right multiplexor 48 (r). This additional output is applied when the mode selector switch 30 is switched to its hemo mode.

[0023] A timer 70 is used to control operation and provide overload protection. The timer, which is a conventional component, is enabled by a foot switch 72 conventionally used by the surgeon to activate the apparatus. The activation can also be built into the handpiece. See also the referenced '759 patent. When the foot switch is activated, the timer supplies (not shown) operating voltages via lines 72 to the RF generator 10 and also to a set of indicators 74, for example, LEDs, and an audible circuit 76 (Fig. 1). A timer output when enabled turns on a desired indicator, indicating, for example, to the surgeon that the electrosurgical currents are available at the handpiece. If desired, the timer output can also be transmitted via the mode selector switch 30 so that different colored lights are turned ON depending on the selected mode. Simultaneously, the audible circuit 76 can be activated so that the surgeon also receives an audible indication when RF power is available. Conveniently, the audio tone is supplied by another pulse frequency outputted on line 78 from the multipulse generator 32. A suitable frequency is 2 kHz which is also an integer multiple of one of the other frequencies generated.

[0024] It is important to prevent overloading (overheating) of the RF oscillator and to prevent possible patient harm. To achieve this function, again a pulse frequency can be derived from the multipulse generator 32 to control the ON/OFF state of the timer. This frequency can again be an integer divisor derived from the oscillator source 36 via the divider 34. The period of such a frequency can be chosen to be about 10 seconds (s), so that the ON time of the timer when activated is limited to the 10s, after which the timer shuts down the operation to avoid overloading. If desired, another frequency can

be derived from the divider to automatically turn back ON the timer after, say 30s, which by then will have allowed the circuit to cool down to prevent overheating. In this mode of operation, so long as the foot switch 72

5 is depressed, the electrosurgical currents will have a duty cycle of 10s ON and 30s OFF. Other duty cycles can obviously be substituted if desired by choosing a different pulse frequency. The operation of the timer is straightforward. A number is programmed in to represent the maximum count of its input pulses, which when reached generates an output control signal that can be used to deactivate, for example, a relay whose contacts supplied power to the various components. The duty cycle can also be readily changed by programming in a different number.

[0025] Not shown is a voltage control device for controlling the output power of the electrosurgical currents, with the high power for maximum output preferably selected at 50 watts, the power being controlled down to approximately 5 watts. This output power control is preferably accomplished by controlling the amplitude of the modulating signal that is applied to the drain input of the MOS driver. This has the advantage that it helps stabilize the output frequency.

20 [0026] The apparatus according to the invention provides a stable and controllable source of high frequency electrosurgical energy in all operational modes. Safety and effectiveness are also present. Apparatus built according to the principles described herein can be 25 designed to meet the international safety standards specified by the International Electrotechnical Commission.

[0027] While the invention has been described in connection with preferred embodiments, it will be understood that modifications thereof within the principles outlined above will be evident to those skilled in the art and thus the invention is not limited to the preferred embodiments but is intended to encompass such modifications.

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Claims

1. Electrosurgical apparatus comprising:

45 a) an active output for connection to an electrosurgical handpiece,
 b) an RF generator for generating an RF carrier for producing first electrosurgical currents capable of an electrosurgical cut mode of operation,
 50 c) first means for generating first and second modulating currents, the first modulating currents when combined with the RF carrier producing second electrosurgical currents capable of a cut/coag mode of operation, the second modulating currents when combined with the RF carrier producing third electrosurgical currents capable of an electrosurgical hemo mode

of operation.

d) selector means for selectively combining the RF carrier with the first or the second modulating currents or with neither of the first or second modulating means to selectively produce electrosurgical currents capable of the cut, cut/coag, or hemo modes of operation, respectively, said means for selectively combining being connected to the active output to provide at the output the electrosurgical currents capable of the selected mode,

e) said first means comprising:

- i) second means for generating a sequence of address codes,
- ii) third means comprising a digitally controlled analog switch having plural channels for receiving and being responsive to the address codes for generating an approximate sine-wave capable of being used to produce the first and second modulating currents.

2. Electrosurgical apparatus as claimed in claim 1, wherein the second means comprises means for generating multiple trains of pulses at frequencies that are integer divisors of each other.

3. Electrosurgical apparatus as claimed in claim 1, wherein the third means comprises means in response to the means for generating multiple trains of pulses for selectively generating at an output a stepped signal that varies from a maximum to a minimum and from the minimum to the maximum.

4. Electrosurgical apparatus comprising:

- a) an active output for connection to an electrosurgical handpiece,
- b) an RF generator for generating an RF carrier for producing first electrosurgical currents capable of an electrosurgical cut mode of operation,
- c) first means for generating first and second modulating currents, the first modulating currents when combined with the RF carrier producing second electrosurgical currents capable of a cut/coag mode of operation, the second modulating currents when combined with the RF carrier producing third electrosurgical currents capable of an electrosurgical hemo mode of operation,
- d) selector means for selectively combining the RF carrier with the first or the second modulating currents or with neither of the first or second modulating means to selectively produce electrosurgical currents capable of the cut, cut/coag, or hemo modes of operation, respec-

tively, said means for selectively combining being connected to the active output to provide at the output the electrosurgical currents capable of the selected mode,

e) said first means comprising:

- i) an oscillator for generating a waveform at a first frequency,
- ii) a binary counter/divider for receiving the waveform at the first frequency and producing from it pulsed sequences at at least second, third, and fourth frequencies, the second, third and fourth frequencies being integer divisors of the first frequency,
- iii) a digitally controlled analog switch having plural channels each having an output connected via a voltage source to a different load, the digitally-controlled analog switch receiving and being responsive to the second, third and fourth frequencies for activating one of the plural channels at a time in sequence to connect in sequence the different loads,
- iv) means for combining the voltage levels appearing across the different loads to generate an approximate sine-wave capable of being used to produce the first and second modulating currents.

5. Electrosurgical apparatus as claimed in claim 4, wherein the second, third, and fourth frequencies constitute a 1 of 8 binary code.

6. Electrosurgical apparatus as claimed in claim 4, further comprising a plurality of different impedances connectable to the analog switch output, said impedances having values such that they are capable of forming voltage dividers which cause the analog switch output to acquire voltages varying in steps between maximum and minimum values.

7. Electrosurgical apparatus as claimed in claim 4, further comprising a smoothing filter connected to the analog switch output.

8. Electrosurgical apparatus as claimed in claim 4, wherein the means for combining the voltage levels includes means for combining sequences of half sine-waves to produce a fully rectified sine-wave serving as the first modulating current.

9. Electrosurgical apparatus as claimed in claim 4, wherein the means for combining the voltage levels includes means for combining sequences of alternate half sine-waves to produce a half-wave rectified sine-wave serving as the second modulating current.

10. Electrosurgical apparatus as claimed in claim 4, further comprising a timer operable to receive a frequency that is an integer divisor of the first frequency for generating an ON-OFF duty cycle for controlling operation of the apparatus. 5

11. Electrosurgical apparatus as claimed in claim 4, further comprising indicators operable to receive a frequency that is an integer divisor of the first frequency for indicating various functions of the apparatus. 10

12. Electrosurgical apparatus as claimed in claim 4, further comprising an audio circuit operable to receive a frequency that is an integer divisor of the first frequency for audibly indicating various functions of the apparatus. 15

13. In combination: 20

(i) an electrosurgical handpiece;

(ii) low power electrosurgical apparatus comprising:

A) an active output for connection to the electrosurgical handpiece, 25

B) an RF generator for generating an RF carrier for producing first electrosurgical currents capable of an electrosurgical cut mode of operation,

C) first means for generating first and second modulating currents, the first modulating currents when combined with the RF carrier producing second electrosurgical currents capable of a cut/coag mode of operation, the second modulating currents when combined with the RF carrier producing third electrosurgical currents capable of an electrosurgical hemo mode of operation, 30

D) selector means for selectively combining the RF carrier with the first or the second modulating currents or with neither of the first or second modulating means to selectively produce electrosurgical currents capable of the cut, cut/coag, or hemo modes of operation, respectively, said means for selectively combining being connected to the active output to provide at the output the electrosurgical currents capable of the selected mode, 40

E) said first means comprising: 45

a) an oscillator for generating a waveform at a first frequency,

b) a binary counter/divider for receiving the waveform at the first frequency and producing from it pulsed sequences at at least second, third, and fourth frequencies, the second, third and fourth frequencies being integer divisors of the first frequency, 50

c) a digitally controlled analog switch having plural channels each having an output connected via a voltage source to a different load, the digitally-controlled analog switch receiving and being responsive to the second, third and fourth frequencies for activating one of the plural channels at a time in sequence to connect in sequence the different loads,

d) means for combining the voltage levels appearing across the different loads to generate an approximate sine-wave capable of being used to produce the first and second modulating currents;

(iii) the first, second and third electrosurgical currents capable of the cut, cut/coag, or hemo modes of operation, respectively, being generated without benefit of a microcontroller. 55

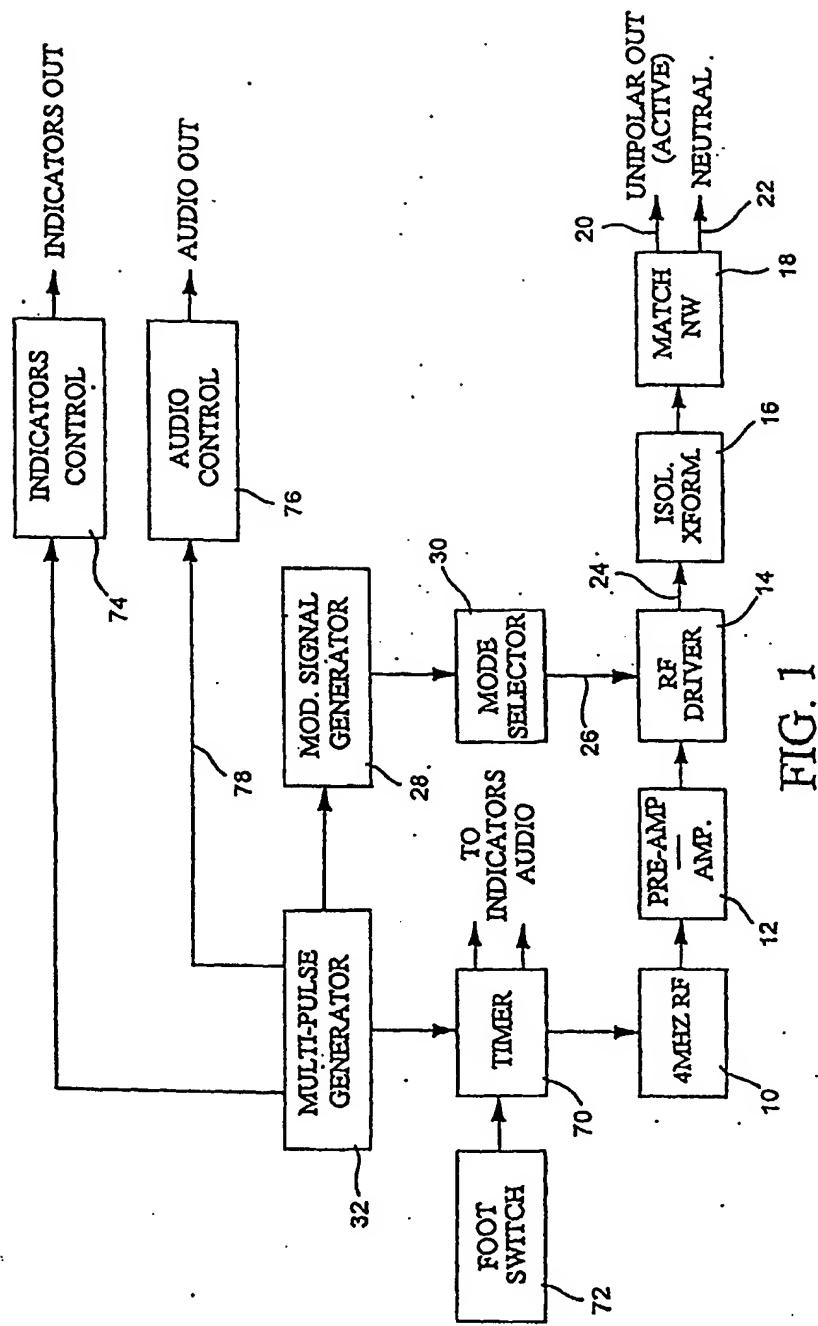


FIG. 1

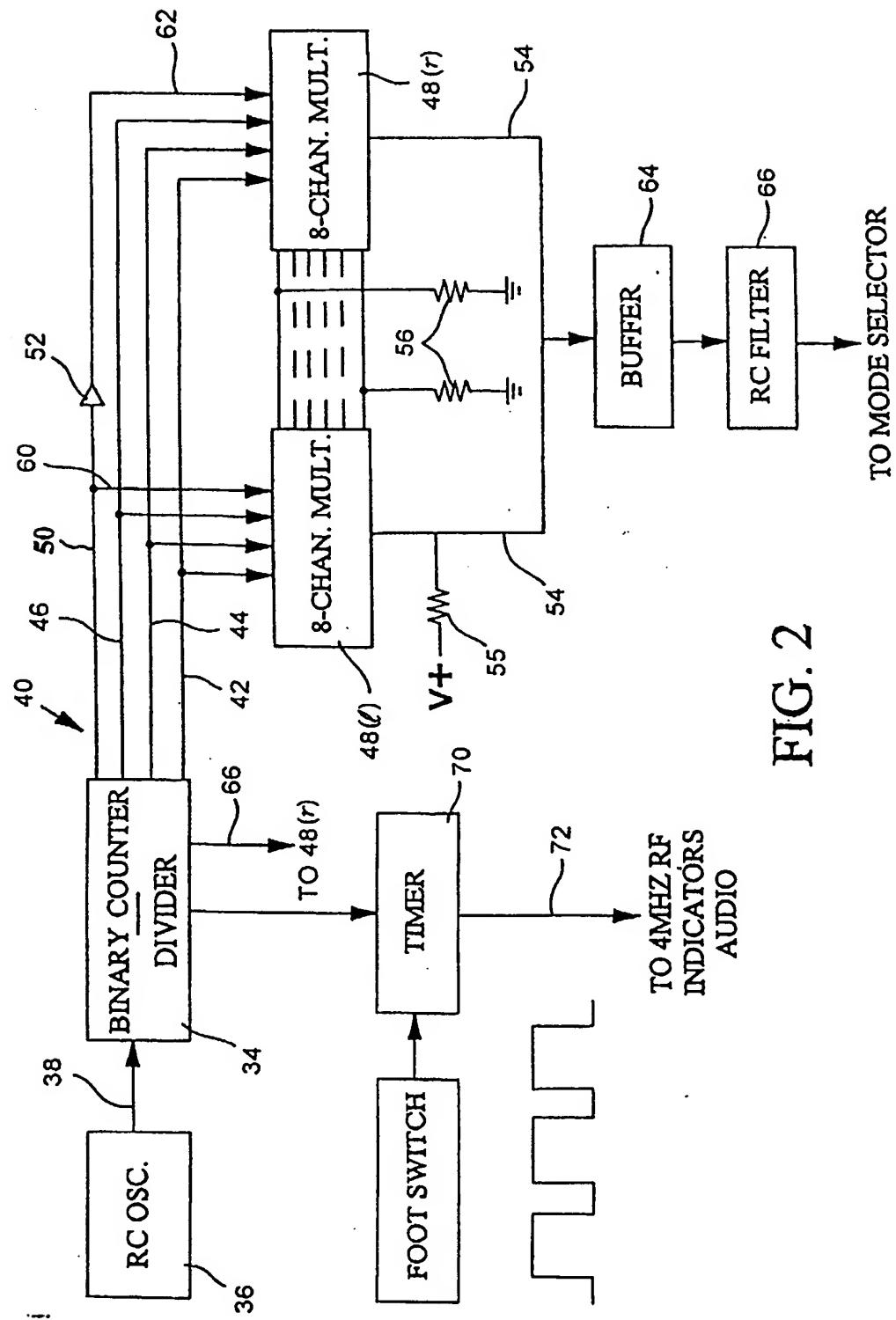
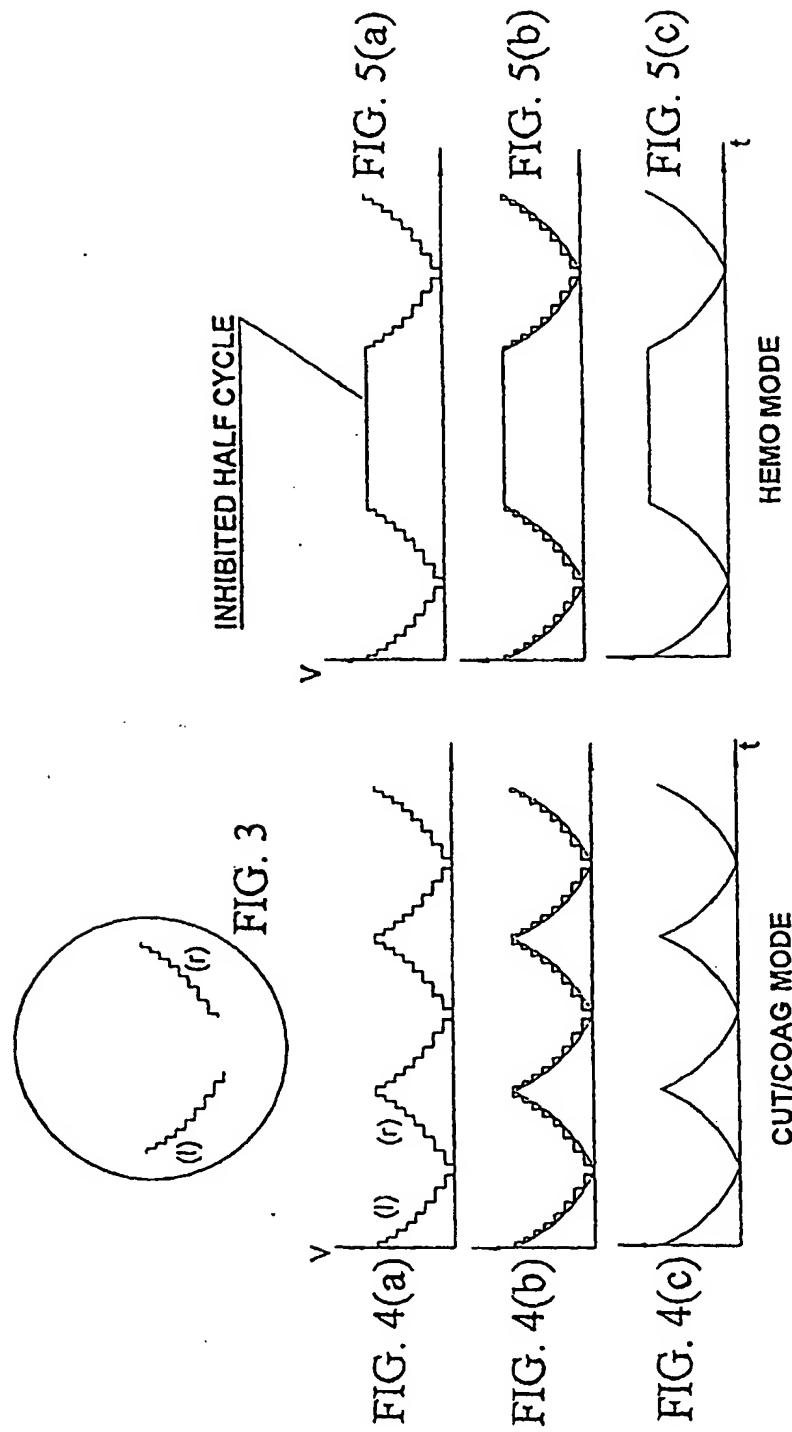


FIG. 2





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EUROPEAN SEARCH REPORT

Application Number
EP 00 30 7115

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Place of search THE HAGUE	Date of completion of the search 23 January 2001	Examiner Papone, F	
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